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To: All Field Officials

From: Director

Subject: Technical Reference 3031-1 "Mineral Deposit Types and Their Characteristics"

Energy and mineral resources assessment are conducted by industry as well as by different government agencies for a variety of reasons. In BLM's case the driving force is a policy need related to the management of public lands through land-use planning.

In subsection .31 Mineral Occurrence Models of the 3031 Manual on Energy and Mineral Resources, the mineral specialist is encouraged to use models when assessing the potential for the occurrence of energy and mineral resources. Geologic models are key to understanding the potential for the occurrence of energy and mineral resources that a given area might have.

Over the years numerous models for different types of mineral deposits have been proposed, but their descriptions are dispersed in the professional literature. To facilitate the work of the minerals specialists and the use of models, we have initiated a project whose product is the subject Technical Reference. The authors have compiled, adapted and up-dated the description of 28 models for mineral deposits found mainly in western United States. This technical reference is organized in a three-ring binder so that changes, up-dates, and additions can easily be made.

The mineral specialists are encouraged to use this Technical Reference, add details pertinent to their respective area, and develop new models applicable to a specific area. If you consider that new models should be added for Bureauwide use, do not hesitate to communicate with Jean Juilland at FTS 653-2270.

A limited number of copies have been printed and at least one copy is being distributed to each Field Office. Those offices receiving more than one copy should keep at least one copy in the library.

Robert H. Lawton

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1 Attachment (sent under separate cover to addressees only):
1 - Technical Reference 3031-1 "Mineral Deposit Types and Their Characteristics"

PREFACE

MINERAL DEPOSIT TYPES AND THEIR CHARACTERISTICS is a compilation and adaptation of existing information for Bureau of Land Management (BLM) use. The title might have been enhanced by including the term "mineral models" but the present title is more in keeping with the intent to make this presentation less complex and more basic. However, the two terms, "mineral types" and "mineral models" are used interchangeably in this report.

Mineral deposit characteristics, or attributes, or models are described as working hypotheses developed by observation, description, statistical data, or analogy of a phenomenon or process that cannot be observed directly, or that can be observed with great difficulty. The term "mineral deposit model" is currently popular for describing an age-old procedure of recognizing consistent geologic, geochemical and/or geophysical features that are considered to be related to, or the cause of, a certain type of mineral deposit. In its simplest form it has been used by prospectors and explorers for many years. In the last three decades improvement in analytical instruments and techniques has made it possible to partially understand the various interacting geologic, geochemical and geophysical processes that take place in the formation and emplacement of a certain type of mineral deposit. Also with increased dissemination of geologic information which is now available, the characteristics of deposits can be compared worldwide and analyzed for their critical and non-critical attributes.

The deposit types included in this report have been compiled from existing literature. They partially resemble a series of models published several years ago by the U.S. Geological Survey as Open Files Reports (82-795, 83-423, 83-623, 83-901, and 83-902) . However, additional information from other publications and from personal files has been included. Selected models were expanded and revised to fit the type of deposits found mainly in western United States.

As our scientific knowledge advances, existing mineral types are improved and refined, and new types are developed, this report can be updated and changed as necessary. The user is strongly encouraged to develop his own models for a specific region if the need arises.

MINERAL DEPOSIT TYPES AND THEIR CHARACTERISTICS

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INTRODUCTION

Assessment of the potential for energy and mineral resources is a complex and difficult process which involves integration of many diverse factors. While some of these factors can be measured, others are judgemental and depend on the experience and knowledge of the mineral specialist making the assessment. To alleviate this intricate and trying process, the geologic profession has systematically arranged the information that describes the characteristics and essential attributes of a group of mineral deposits sufficiently similar that they suggest a related origin. This is the basic technique used in mineral modeling and it is an ever-evolving process that is constantly being refined. It is considered by most explorationists as an essential tool for understanding the potential that a given area might have for the occurrence of a mineral deposit.

There are several types of models, descriptive, genetic, probability of occurrence, grade-tonnage, and qualitative models, all based on increasing complexity. For BLM assessment work, the descriptive type is the most useful in most cases and is the one used in this report.

Because of different objectives, the use of mineral deposit models by the BLM is somewhat different. The areas which have to be assessed (target areas) have been already defined - the Resource Areas. The available geologic, geochemical, geophysical and mineral occurrence data are matched with the characteristics of existing models for various types of energy and mineral deposit. In addition, use of models can help the Bureau's mineral specialist determine what additional information may be needed for determining the mineral potential and/or for increasing the level of certainty as to whether a deposit is likely to occur.

The use of mineral deposit models technique helps the mineral specialist organize ideas and information while focusing on energy and mineral resources potential. It enables the mineral specialist to compare his/her observations with the collective knowledge of a wide group of experts. A major determinant of credibility is excellent documentation; using mineral deposit models, documents the assessment process thus allowing prompt revision whenever necessary and providing background support whenever the results are questioned. All these advantages will enhance the Bureau's ability to produce authoritative energy and mineral resources assessments.

The use of mineral deposit models by BLM would be primarily in the GEM resources assessment for input to planning, and other instances where the potential for energy and mineral resources needs to be assessed.

In the GEM resources assessment the mineral deposit models technique is used as follows:

(1) Define area of interest. For input to planning the area of interest is usually the Resource Area.

(2) Literature search; obtain and organize geologic, geochemical, geophysical, mineral and other pertinent data.

(3) Match available data with available models and select those models with which there is complete or predominant coincidence.

(4) Identify additional data if any are needed.

(5) Using appropriate models and available data, classify the land as to its potential for energy and mineral resources.

The 3031 Manual gives detail for the preparation of an assessment.

The deposit types presented in this report are arranged according to five basic modes of occurrence. These are felsic plutonic, submarine volcanic-hosted, vein and replacement (epigenetic), sediment-hosted, and sedimentary. The numbering system used reflects the group association.

The data that make up each type are subdivided into four main subparts and consist of an introductory section, a section on geologic features, a section on mineral characteristics, and a list of deposit examples and literary references. When available, a cross-section illustration of the type is also included.

In the introductory section of a deposit type, the common or scientific name in current use is given under **Deposit Type**. If there are important distinctions from the general type, a separate subtype is developed and named under **Subtype** and denoted by an A, B, etc. When there is another commonplace name for the type, this name is given under **Synonym**.

The **GEOLOGIC FEATURES** subpart contains **Regional Setting** where a description is given of the general tectonic position(s), related structural features, and relative age. Next, is **Structural Features** where the type and orientation of favorable fractures, faults, lineament patterns, and intrusive bodies are discussed. The last item of this subpart is **Stratigraphic and Lithologic Characteristics** which describes recognized favorable formations and rock types (host rocks).

Under the **MINERAL CHARACTERISTICS** subpart, **Deposit Features** describes in general the size, shape, grade and tonnage range, the ore, and associated minerals and commodities usually found. Next, listed under **Alteration** is a description of the types and patterns of hydrothermal alteration commonly found with the respective mineral deposit. Related stratigraphic, structural, and/or geochemical influences on the deposit are listed next under **Ore Control**. Any special weathering characteristics or secondary minerals that might serve as a prospecting guide are given under **Weathering**. Anomalous (either enriched or depleted) amounts of any pathfinder elements in or near a deposit and the zonal pattern are noted under **Geochemical Expression**. Under **Geophysical Expression**, any geophysical signature known to be associated with a particular type is described.

The last subpart is a list of **Deposit Examples** arranged by state with the corresponding literature reference. This is not an all inclusive list, but rather a list of some of the more typical deposits of this type. Also, some experts disagree on the proper classification of the deposits listed. The **References** chosen were the most up-to-date that still gave the best overall general description.

Deposit Type: PORPHYRY COPPER.

Subtype: This is for the general type. A few deposits can be differentiated into molybdenum-rich and/or gold-rich copper porphyries, but the observable differences are very subtle.

Description: A disseminated replacement deposit in which the copper minerals occur as discrete grains and closely spaced veinlets (stockwork) in a large volume of rock that is nearly always porphyritic.

GEOLOGIC FEATURES

Regional Setting: Continental margins or fragments of margins having abundant igneous intrusive rocks ranging principally from Mesozoic to Tertiary in age.

Structural Features: Most deposits are spatially or genetically related to intrusives that form as stocks, plugs, sills, or dikes. The intrusive action may be forceful, passive or permissive, but the larger deposits seem to favor passive intrusions. Breccia and brecciation pipes are common around some deposits.

Stratigraphic and Lithologic Characteristics: The intrusive rocks may range widely in composition, but quartz-bearing intermediate rocks are most common. Such types as quartz monzonite, granodiorite, and tonalite are favorable. At least one facies of the intrusive is porphyritic with a microgranular aphanitic quartz- feldspar groundmass. Carbonate rocks are particularly favorable when intruded by an intermediate to felsic porphyry. Siliceous metamorphic and other sedimentary rocks are next in order of preference.

MINERAL CHARACTERISTICS

Deposit Features: There is no predominate shape; some are flat or saucer-shaped whereas others are pipe-like with a circular or oval cross-section. Where figures are available, tonnages are in the 20 to 1100 million range. Copper content commonly ranges from 0.30 to 1.00 percent; molybdenum, 0.015 to 0.1 percent; gold, 0.10 to 0.65 g/ton; silver, 0 to 4.0 g/ton. Supergene sulfides may form a higher grade zone of secondary enrichment. Primary minerals are pyrite, chalcopyrite, and molybdenite. Less common is bornite, enargite, and scheelite. The gold and silver rarely form distinct minerals.

Alteration: One type of alteration or another is always found accompanying this type of mineralization. Five distinct types have been recognized. Propylitic alteration is characterized by lime-bearing minerals such as calcite and epidote and is generally found at the outer edges of the porphyry area. Argillic alteration is characterized by the presence of clay minerals (kaolinite or montmorillonite group) and by strong leaching of lime minerals giving a bleached look to the rocks. Potassic alteration is characterized by the assemblage of muscovite-biotite-potassium feldspar (no clay minerals are formed). Quartz-sericite alteration is marked by the absence of clay and potassium feldspars. Lime-silicate alteration occurs when carbonate sediments are replaced with lime-silicate minerals at the intrusive contact. Not all deposits display all five types; in fact, some only exhibit one or two. Some deposits have been found to have undergone simultaneous alteration of different types at separate points within the same deposit. Others show repeated episodes of alteration over time.

Ore Controls: Mineralized closely spaced fractures and faults as the result of folding, and doming of the host rocks are necessary to allow access for the ore-forming solutions.

Weathering: The surrounding surface area may show widespread iron oxide staining depending upon the original amount of pyrite in the rocks and the degree of weathering. Frequently a leached capping forms over a deposit. If the area has undergone long periods of erosion, these features may be largely removed or buried beneath alluvium.

Geochemical Expression: Anomalous amounts of copper, molybdenum, gold, silver, and tungsten are found in the central part of a deposit. Lead, zinc, gold, silver, molybdenum, arsenic, antimony, tellurium, manganese, and rubidium may be found in the peripheral areas.

On a regional basis, stream sediment values that might be anomalous are:

Cu 50-100 ppm
Pb 50-100 ppm
Te 100-400 ppb

For a district-wide reconnaissance, anomalous values for stream sediments are:

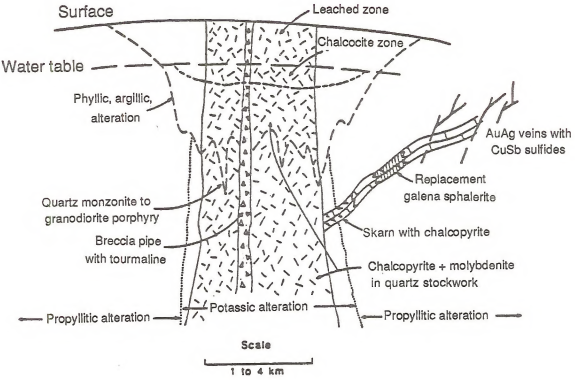
Cu	100 ppm	Mn	1000 ppm
Pb	100 ppm	zn	100 ppm
Te	400 ppb	Mo	5 ppm
Ag	0.5 ppm		
Au	50 ppb		

Geophysical Expression: Although magnetic methods have not been successful in directly finding deposits, it has been noted that some deposits are situated on the flanks of magnetic highs. Induced polorization has been used to detect pyrite halos that surround some porphyries. Other methods have been largely unsuccessful. When potassic alteration is present and exposed at the surface, gamma-ray spectrometry surveys could detect the potassium rich zone.

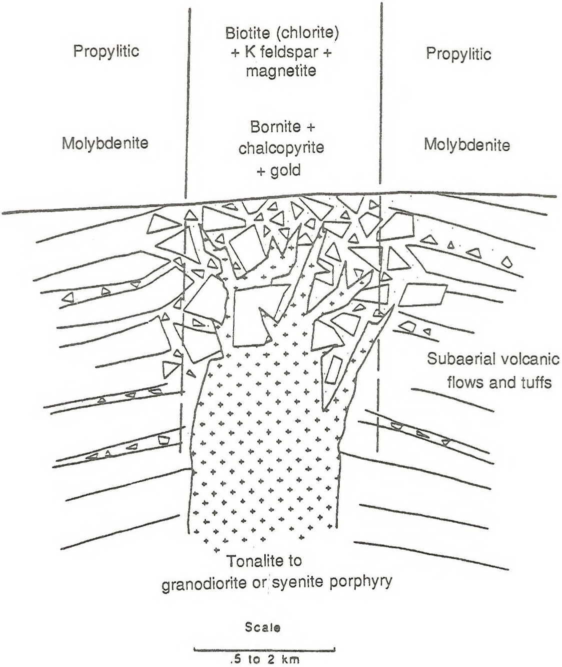
Associated Mineralization: Lead, zinc and silver veins are frequently found at the outer fringes of a porphyry system. In a few deposits, deep erosion has produced placer gold downstream from the main mineralization.

Deposit Examples:	References:
Bond Creek (AK)	Singer and Mosier, 1983
Orange Hill (AK)	Singer and Mosier, 1983
Ajo (AZ)	Dixon, 1966
Bagdad (AZ)	Anderson et al., 1956
Bisbee (AZ)	Bryand and Metz, 1966
Bluebird (AZ)	Singer and Mosier, 1983
Carpenter (AZ)	Singer and Mosier, 1983
Castle Dome (AZ)	Peterson, 1962
Christmas (AZ)	Koski and Cook, 1982
Copper Basin (AZ)	Johnston and Lowell, 1961
Copper Cities (AZ)	Simmons and Fowells, 1966
Copper Creek (AZ)	Singer and Mosier, 1983
Dos Pobres (AZ)	Langon and Williams, 1982
Florence (AZ)	Nason et al., 1982
Helvita (AZ)	Creasey and Quick, 1955
Inspiration (AZ)	Olmstead and Johnson, 1966
Ithica Peak (AZ)	Dings, 1952
Kalamazoo-San Manuel (AZ)	Lowell, 1968
Lakeshore (AZ)	Hallof and Winniski, 1971
Metcalf (AZ)	Moolick and Durek, 1966
Miami (AZ)	Peterson, 1962
Mineral Butte (AZ)	Singer and Mosier, 1983
Pima-Mission (AZ)	Kinnison, 1966
Ray (AZ)	Metz and Rose, 1966
Red Mountain (AZ)	Corn, 1975
Sacaton (AZ)	Cummings, 1982
Safford (AZ)	Robinson and Cook, 1966
Sanchez (AZ)	Singer and Mosier, 1983
San Juan (AZ)	Blake, 1971
San Xavier (AZ)	King, 1982
Sierrita-Esperanza (AZ)	West and Aiken, 1982
Silver Bell (AZ)	Graybeal, 1982
Twin Buttes (AZ)	Barter and Kelly, 1982
Vekol (AZ)	Chaffee, 1977
Lights Creek (CA)	Storey, 1978
Catheart (MN)	Singer and Mosier, 1983
Butte (MT)	Meyer, 1968
Heddleston (MT)	Singer and Mosier, 1983
Bear (NV)	Singer and Mosier, 1983
Copper Canyon (NV)	Nash and Theodore, 1971
Ely (NV)	Bauer et al., 1966
MacArthur (NV)	Singer and Mosier, 1983
Yerington (NV)	Wilson, 1963

Deposit Examples:	References:
Hillsborough (NM)	Dunn, 1982
Santa Rita (NM)	Rose and Baltosser, 1966
Tyrone (NM)	Kolessar, 1982
Bingham (UT)	James, 1978
American River (WA)	Hollister, 1979
Buckindy (WA)	Hollister, 1979
Camp Creek (WA)	Hollister, 1979
Crescent (WA)	Hollister, 1979
Glacier Peak (WA)	Hollister, 1979
Goat Haven (WA)	Hollister, 1979
Gold Mountain (WA)	Hollister, 1979
Manzama (WA)	Hollister, 1979
Margaret (WA)	Hollister, 1979
Middle Fork (WA)	Hollister, 1979
Mineral Creek (WA)	Hollister, 1979
Miners Queen (WA)	Hollister, 1979
Monument (WA)	Hollister, 1979
North Fork (WA)	Hollister and Baumann, 1978
Red Mountain (WA)	Hollister, 1979
Ross (WA)	Hollister, 1979
Round Mountain (WA)	Hollister, 1979
Silver Creek (WA)	Hollister, 1979
Sunrise (WA)	Hollister, 1979
Van Epps (WA)	Hollister, 1979
Cloud Home Peak (WY)	Fisher, 1982
Deer Creek (WY)	Fisher, 1982
Eagle Creek (WY)	Fisher, 1982
Kirwin (WY)	Fisher, 1982
Needle Creek (WY)	Fisher, 1982



Idealized section through a molybdenum-rich variant of a porphyry copper deposit (from USGS Open File Report 83-423)



Idealized section through a gold-rich variant of a porphyry copper deposit (from USGS Open File Report 83-423)

Deposit Type: PORPHYRY MOLYBDENUM

Subtype: Climax or granite type.

Description: A stockwork containing disseminated grains and veinlets of quartz and molybdenite in a fractured or brecciated, hydrothermally altered granite porphyry intrusive.

GEOLOGIC FEATURES

Regional Setting: Confined mainly to the continental interior and in belts of Cretaceous-Tertiary tectonic activity that were disturbed by subsequent igneous activity. The deposits show some relations to rift zones that are characterized by continental rhyolite-basalt associations.

Structural Features: Complex structural intersections probably served to locate the intrusives, but surface indications are not always present. The deposits commonly occur in clusters or groups within an area 5 to 20 miles in radius. Ore bodies tend to be dome-shaped and centered on intrusive cupolas. Simple to composite intrusives, dikes and breccia pipes localize the ore. Such features as steeply dipping radial and concentric dikes, veins, faults, and joints are indicative of forceful emplacement of magmatic cupolas. Intensive, widespread, and continued fracturing of host intrusives and enclosing country rocks is characteristic. Almost invariably one or more major faults pass through or close by the ore bodies.

Stratigraphic and Lithologic Characteristics: Deposits of this type are found in high silica, alkali-rich porphyry granites having glassy and sometimes smoky quartz phenocrysts. These granites are mid-Tertiary or younger in age. Favorable granites will have ≥250 ppm rubidium, ≤50 ppm strontium, ≥50 ppm niobium, ≤300 ppm barium, and be enriched in fluorine and tin.

MINERAL CHARACTERISTICS

Deposit Features: Many complex shapes are exhibited, but the domal, funnel-shape, accuate, and annular bodies are most common. The deposits may range from a few hundred to several thousand feet in horizontal dimension and may extend to depths of several thousand feet. Commercial deposits range in size from about 50 to 900 million tons. Molybdenite as the ore mineral, forms disseminations and veinlets giving an overall grade of 0.1 to 0.3 percent molybdenum. This is accompanied by pyrite, fluorite, small amounts of tungsten, tin, and zinc minerals. Fluorite and/or topaz are especially notable by their presence in most deposits.

Alteration: Intense hydrothermal alteration of the host intrusive as well as of country rock is always displayed. The degree and sequence of the alteration stages varies widely among deposits. A zonal pattern is commonly displayed with intense quartz and potassium feldspar veins in the orebody followed by argillic and propylite alteration above and along the sides of the main mineralization. Greisen veins found below and sometimes extending through the ore zone are thought to represent a late barren stage.

Ore Controls: Intense fracturing of the intrusive and intruded rocks allowed hydrothermal fluids to permeate the region over small cupolas. The involved rock must be competent enough to prevent venting and escape of the ore-bearing fluids.

Weathering: The surface expression relates to the amount of erosion and the degree alteration present. Many deposits show striking color variation due to black manganese oxides, yellows from ferrimolybdenite, jarosite, and limonite, bright reds from lepidocrosite and hematite all against a background of bleach rock. Probably the most consistent feature is the iron staining for oxidized pyrite in the ore body (if exposed).

Geochemical Expression: Anomalous amounts of molybdenum, tin, and tungsten are found especially above the deposit. A zinc and lead halo may show a half mile or more from a deposit. A low silver halo is sometimes found outside the zinc anomaly. Fluorite is found through and around the mineralization area most often in the form of pale blue or green variety. Copper is abnormally low.

Geophysical Expression: Gravity lows of moderate to large intensity and of small areal extent may reflect both the siliceous rocks and the alteration around mineralized cupolas, depending on the density of the host rock. There is some evidence to suggest that favorable areas are along the margins of large regional gravity lows that are presumed to reflect a buried parent mass of batholithic size. Induced polarization may detect ore zones of molybdenite and/or quartz-sericite-pyrite alteration. Generally, none of the current geophysical methods have been overly successful in detecting this type of deposit.

Associated Mineralization: Tin in the form of cassiterite and tungsten as huebnerite or wulfenite may be present in high enough quantities to be recovered as a co-product. Above the main molybdenum mineralization zone, it is not uncommon to find a broad zone of veins and veinlets of base metal sulfides, rhodochrosite, and fluorite.

Deposit Examples:	References:
Chicago Basin (CO)	Schmitt and Raymond, 1977
Climax (CO)	White et al., 1981
Hahns Peak (CO)	Segerstrom and Young, 1972
Henderson-Urad (CO)	Wallace, 1978
Horseshoe Bend (CO)	Burbank and Luedke, 1964
Leavenworth Creek (CO)	Taylor and King, 1967
Mount Antero (CO)	Dings and Robinson, 1957
Mount Emmons (CO)	Thomas and Galey, 1978
Nye (CO)	Harshman, 1965
Redwell (CO)	Sharp, 1978
Treasure Mountain (CO)	Mutschler, 1976
Turquoise Lake (CO)	Tweto, 1974
Winfield (CO)	Ranta, 1974
Cumo (ID)	Shannon, 1971
Ima (ID)	Rostad, 1971
Little Falls (ID)	Rostad, 1966
Bald Butte (MT)	Rostad, 1969
Big Ben (MT)	Witkind, 1973
Emigrant Gulch (MT)	Kirkemo et al., 1965
Majuba Hill (NV)	MacKenzie and Bookstrom, 1976
McDermitt (NV)	Greene, 1976
Mount Hope (NV)	Merriam and Anderson, 1942
Questa-Goat Hill (NM)	Leonardson et al., 1982
Cave Peak (TX)	Sharp, 1979
Marysvale (UT)	Nuella et al., 1979
Pine Grove (UT)	Abbot and Williams, 1981
Sand Pass (UT)	Ludington, 1982

Deposit Type: PORPHYRY MOLYBEDNUM

Subtype: Fluorine-deficient type

Synonym: Calc-alkaline molybdenum stockwork

Description: A stockwork containing disseminated grains and veinlets of quartz and molybdenite in fractured and brecciated, hydrothermally altered felsic porphyry.

GEOLOGIC FEATURES

Regional Setting: Confined mostly to continental margins and areas of back-arc spreading associated with converging plate margins in intercratonic rifts.

Structural Features: The deposits generally parallel the tectonic grain of Mesozoic batholiths and are probably controlled by the overall extent of the associated igneous rocks. Many deposits are related to small intrusives that are satellites of a batholith. Location of the deposits suggests that they are more than casually related to the western U.S. porphyry copper belt.

Stratigraphic and Lithologic Characteristics: Favorable host rocks are monzonites, quartz monzonite, quartz granodiorites, and quartz diorites. The texture should exhibit conspicuous quartz phenocrysts set in a well-developed, microgranular quartz-potassium feldspar ground mass. One of the diagnostic indicators of this type of deposit is abundant, closely spaced quartz veinlets throughout large volumes for rock (stockworks). Age of the intrusives range from late Cretaceous to late Tertiary. Age of the intruded rocks may range as old as Upper Cambrian. Plutons favorable to this type of deposits have 100-250 ppm rubidium, 100-200 strontium, and 20 ppm niobium.

MINERAL CHARACTERISTICS

Deposit Features: The main mineralization consists of molybdenite and pyrite disseminated and in veinlets and fractures. Minor amounts of associated scheelite and chalcopyrite may occur. Molybdenum content commonly ranges from 0.05 to 0.15 percent. Fluorine content is low (0.25 percent) and tin is usually absent. Pyrite content is known to increase in the upper parts of some deposits and secondary enrichment of copper may occur in the central part of the system. Most deposits are crudely circular in size and less than 1500 meters in diameter. Tonnages range from about 15 to 700 million tons.

Alteration: Most deposits show a potassic core, a quartz-sericite-pyrite intermediate zone, an outer and upper argillic zone, and a propylitic halo. The highest concentration of molybdenite is found at the outer edge of the potassic zone and within the inner quartz-sericite-pyrite zone. Minor amounts of chalcopyrite may surround the molybdenite mineralization zone.

Ore Controls: Mineralization is controlled by the stockwork of fractures and breccia zones within the intrusive. Ore minerals may stop abruptly at the intrusive contact or gradually diminish in occurrence.

Weathering: Surface features will vary considerably depending on the degree and amount of erosion of the ore body. Oxidation of the pyrite will produce widespread iron staining. Molybdenite may oxidize into yellow ferrimolybdenite and copper into green oxide stains.

Geochemical Expression: Many deposits showing a zoning outward and upward from molybdenum to copper to zinc and gold to lead, gold, and silver. Productive stockworks typically show 70-300 ppm molybdenum and 20-40 ppm tungsten. Soils are found to be reliable in some areas while rock sample are better in others.

Geophysical Expression: Very few of the known deposits have documented geophysical signatures. If the molybdenite and/or pyrite veinlets are concentrated enough, electrical and electromagnetic methods might be successfully employed. Also, if hydrothermal alteration has not been intense enough to destroy the primary magnetite, the resulting rocks should show a low magnetic susceptibility. If the potassic core has been exposed by erosion, gamma-ray spectrometry might be used to successfully identify this core.

Associated Mineralization: Sporadic vein deposits of chalcopyrite-enargite-bornite-molybdenite, or pyrite-gold, or sphalerite-gelena-gold-silver are sometimes found in the peripheral zones of productive stockworks.

Deposit Examples:	References:
Burroughs Bay (AK)	Hudson et al., 1981
Quartz Hill (AK)	Hudson et al., 1979
Thompson Creek (ID)	Schmidt, 1978
White Cloud (ID)	Bennett, 1978
Cannivan Gulch (MT)	Schmidt and Worthington, 1971
Turnley Ridge (MT)	Senter, 1976
Buckingham (NV)	Theodore, 1982
Hall (NV)	Kirkemo et al., 1965
Pine Nut (NV)	Schilling, 1962
UV Industries (NV)	Menzie and Theodore, 1983
Mt. Tolman (WA)	Menzie and Theodore, 1983

Deposit Type: IRON SKARN

Subtype: Distinction can be made between calc-iron skarns and magnesium-iron skarns based on tectonic setting, associated intrusive, and related minor metals. In most cases, the outward difference in appearance of either is minor. This model will treat both subtypes as one, noting only the pertinent differences.

Synonym: Contact metamorphic, contact metasomatic, pyrometasomatic, or iron tactite.

Description: Magnetite in coarse-grain Ca-Fe-Mg-Mn silicates formed by the replacement of carbonate-bearing rocks at or near the contact with an igneous intrusive.

GEOLOGIC FEATURES

Regional Setting: Calc-iron deposits are related to island areas and rifted continental margins while magnesium-iron deposits are nearly all found along continental margins.

Structural Features: Deposits form at the contact of a younger igneous intrusive and older carbonate rocks, calcareous clastic rocks, or occasionally in volcanic sequences.

Stratigraphic and Lithologic Characteristics: The magnesium skarns are associated with rocks ranging from gabbros to granites. Calc skarns prefer intrusives of gabbro, diabase, diorite, or syenite having a medium to fine-grain texture and forming large to small stocks and/or dikes. Thinly interbedded sequences of limestone and volcanics seem to be more favorable than thick carbonate beds. Magnesium skarns are usually found in association with hypabyssal stocks and dikes of granodiorite, quartz monzonite, and occasionally in granite. Dolomite is the preferred host rock over limestone. Nearly all the deposits are Mesozoic or younger in age, but could be any age.

MINERAL CHARACTERISTICS

Deposit Features: The ore bodies range from 300,000 tons to 170 million tons and have a typical grade of 40 percent iron. They form tabular to irregular mass along the intrusive contact. Mineralization consists of magnetite and minor amounts chalcopyrite, cobaltite, pyrite, and pyrrhotite. All of these minerals are enclosed in massive amounts of garnet, pyroxene, and epidote that make up the skarn.

Alteration: Widespread and intense alteration of the igneous rocks is more common of the calci type than of the magnesium type. Alteration causes the formation of diopside, hedenbergite, grossularite and andradite garnets, and additional epidote.

Ore Controls: The igneous contact and the attending fractures of the intrusive action are probably the major contributors. Secondary control is probably exerted by the permeability of the carbonate rocks and/or calcareous rocks.

Weathering: No particular distinctive pattern for this type of deposit. Magnetite is somewhat resistant to weathering and should crop out as float. Any pyrite and/or pyrrhotite would oxidize and form the characteristic brown stain on enclosing rocks.

Geochemical Expression: Anomalous amounts of copper, cobalt, and gold can be found around many deposits. In the calc-types addition anomalies of zinc, gold, nickel, molybdenum, and silver are sometimes displayed.

Geophysical Expression: Very little information is available on use of geophysics in exploring for this type of deposits. The most obvious choice would be aeromagnetics for coverage of large areas. Detection response would depend on the amount overburden, thickness and size of the deposit.

Associated Deposits: There are no known associated mineralizations with this type of deposit.

Deposit Examples:	References:
Beck (CA)	Wright et al. 1953
Cave Canyon (CA)	Wright et al. 1953
Eagle Mountain (CA)	Dubois and Brummett, 1968
Iron Hat (CA)	Lamey, 1948
Lake Hawley (CA)	Durrell and Proctor, 1948
Lava Bed (CA)	Lamey, 1948
Old Dad Mountains (CA)	Wright et al. 1953
Shasta-California (CA)	Lamey, 1948
Silver Lakes (CA)	Lamey, 1948
Vulcan (CA)	Lamey, 1948
Elkhorn Peak (MT)	Knopf, 1913
Dayton (NV)	Reeves et al., 1958
Dover (NJ)	Simms, 1958
Capitan (NM)	Kelly, 1952
Copper Flat (NM)	Kelley, 1949
Cuchillo-Negro (NM)	Kelley, 1949
Fierro-Hanover (NM)	Hernon and Jones, 1968
Gallinas (NM)	Kelley, 1949
Iron Mtn.-Colfax Co (NM)	Kelley, 1949
Iron Mtn.-Sierra Co (NM)	Harrer and Kelly, 1963
Jicarilla (NM)	Kelley, 1949
Jones Camp (NM)	Kelley, 1949
Orogrande (NM)	Harrer and Kelly, 1963
Santa Rita (NM)	Harrer and Kelly, 1963
Tecolote (NM)	Kelley, 1949
Yellow Jacket (NM)	
St. Lawrence (NY)	Buddington and Leonard, 1962
Cornwall (PA)	Lapham, 1968
Dillsburg (PA)	Hotz, 1960
French Creek (PA)	Smith, 1931
Grace (PA)	Simms, 1968
Iron Springs (UT)	Mackin, 1968

Deposit Type: COPPER SKARN

Subtype: This is a general type that is sometimes subdivided into skarns associated with porphyry copper deposits and skarns associated with nonporphyry copper deposits. Distinction is made mainly on the basis of size and accessory minerals.

Synonym: Contact metamorphic, contact metasomatic, pyrometasomatic, or copper tactite.

Description: Copper minerals with Ca-Fe-Mg-Mn silicates consisting primarily of garnet and formed by the replacement of carbonate-bearing rocks at or near the contact with an igneous intrusive.

GEOLOGIC FEATURES

Regional Setting: The majority of these deposits are related to the orogenic belt at continental margins. Very few are situated in an oceanic island-arc setting.

Structural Features: Those associated with porphyry copper take on the distinctive features that are found with this type of deposit. The nonporphyry subtype generally has no recognizable structure features but is probably related to zones of weakness that enable the related intrusive to be implanted as stocks and plutons.

Stratigraphic and Lithologic Characteristics: Both subtypes of copper skarns are associated with felsic, porphyry-textured stocks ranging in age mainly from Mesozoic to Tertiary but could be any age. The intruded rocks are carbonate and/or calcareous clastic rocks and can be of any age. All porphyry copper deposits have associated copper skarns that make up between 1 and 100 percent of the ore. Very few large copper skarns are formed when the host rock is wholly dolomitic.

MINERAL CHARACTERISTICS

Deposit Features: By their very nature, the skarns are very irregular in size. Porphyry copper related skarns commonly contain 25 to 385 million tons of open pit ore while nonporphyry skarns may contain only 35,000 tons to 10 million tons. Copper is found mainly in the form of chalcopyrite and lesser amounts of bornite. Grade typically ranges from 1 to 2 percent copper. Intermixed with the copper minerals are varying amounts of pyrite, hematite, magnetite, pyrrhotite, molybdenite, and sphalerite. Accessory minerals of calc skarns are andradite garnet, pyroxene, diopside, epidote, and wollastonite. In magnesium skarns, fosterite, brucite, tremolite, and serpentine commonly form.

Alteration: In the porphyry subtype skarns, alteration can be extensive with a major potassic interzone grading out to sericite and phylite. Intruded rocks are frequently altered to epidote, pyroxene, diopside, and garnet. The nonporphyry subtypes are generally not as extensively altered but have the same mineral assemblages. Carbonate beds can be altered to coarse marble and calcareous beds to hornfels.

Ore Controls: The permeability and bedding planes in the carbonate and/or calcareous rocks are of prime importance in the development of the skarn. Equally important are induced fractures as the result of the intrusive action.

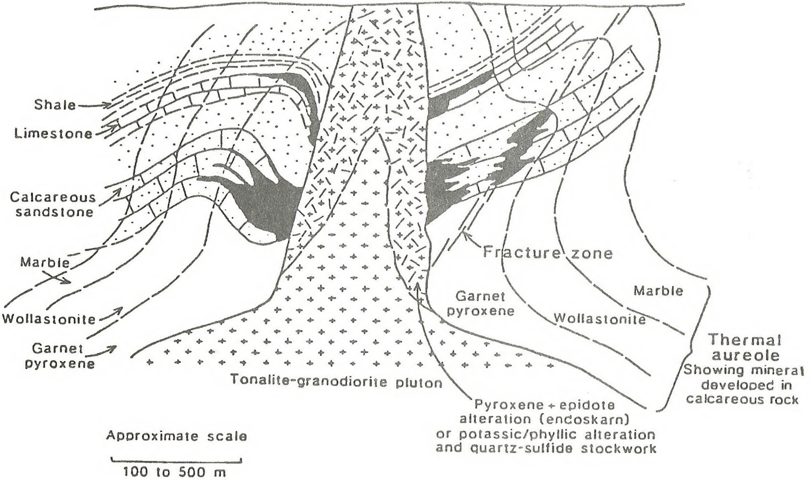
Weathering: Surface erosion will produce copper carbonates and oxides while the iron minerals will frequently form a gossan.

Geochemical Expression: Normally, anomalous amounts of copper, lead, zinc, gold, silver, molybdenum, and possibly bismuth will be present in the general vicinity depending on the size of the deposit and the amount of surface exposure.

Geophysical Expression: Magnetic and/or electric methods could be used, but the results would depend on the amount of magnetite, pyrite, and pyrrhotite in the skarn and the amount of cover if buried. Gravity methods might detect the presence of buried stocks but not whether there were associated skarns.

Associated Mineralization: Besides porphyry copper deposits, some zinc-bearing skarn may form and replacement deposits of lead and zinc may form in the outer marble zones of carbonate beds.

Deposit Examples:	References:
Christmas (AZ)	Perry, 1969
Lakeshore (AZ)	South, 1972
Mission (AZ)	Richard and Courtright, 1959
Morenci (AZ)	Moolick and Durek, 1966
Pima (AZ)	Langlois, 1978
Silver Bell (AZ)	Graybeal, 1982
Twin Buttes (AZ)	Barter and Kelly, 1982
Empire (ID)	Umpleby, 1917
Blue Bell (MT)	Knopf, 1913
Elkhorn (MT)	Klepper et al., 1957
Blue Stone (NV)	Harris and Einaudi, 1982
Casting (NV)	Harris and Einaudi, 1982
Copper Basin (NV)	
Copper Canyon (NV)	Blake et al., 1978
Douglas Hill (NV)	Harris and Einaudi, 1982
Ely (NV)	James, 1976
Ludwig (NV)	Harris and Einaudi, 1982
Lyon (NV)	
Mason Valley-Malachite (NV)	Einaudi, 1977
McConnell (NV)	Harris and Einaudi, 1982
Victoria (NV)	Atkinson et al., 1982
Western Nevada (NV)	Harris and Einaudi, 1982
Continental (NM)	Einaudi, 19822Pinos Altos (NM)
McKnight and Fellows, 1978	
San Pedro (NM)	Smith et al., 1945
Santa Rita (NM)	Nielson, 1970
Snowshoe (NM)	
Carr Fork (UT)	Atkinson and Einaudi, 1978



Idealized section of a copper skarn
(from USGS Open File Report 83-423)

Deposit Type: ZINC-LEAD SKARN

Subtype: Some distinction can be made between those formed near batholiths, near stocks, near dikes, and those distant for any igneous source. Differences are noted mainly on the basis of associated minerals and degree of alteration.

Synonym: Contact metamorphic, contact metasomatic, pyrometasomatic, or zinc-lead tactite.

Description: Sphalerite and galena in calc-silicates associated with carbonate and/or calcareous clastic rocks.

GEOLOGIC FEATURES

Regional Setting: Most deposits occur along continental margins and are related to syngenetic or late orogenic activity.

Structural Features: No particular structural features or orientation noted in most deposits. Those deposits associated with igneous bodies are probably related to zones of weakness that allowed emplacement, but evidence of such may or may not be discernible. One distinctive feature of this type of mineralization is that the skarns occur relatively distal to their magmatic source.

Stratigraphic and Lithologic Characteristics: A wide range of carbonate and calcareous sedimentary rocks can serve as a host for mineralization with no particular preference. Age can range from Paleozoic to Mesozoic. Intrusive rocks can vary from granites and granodiorites to diorite and syenite. Ages of these rocks can span from Paleozoic to Tertiary although most are Mesozoic. The apparent nonselectivity of intrusive and intruded rock types is another distinctive feature of this model.

MINERAL CHARACTERISTICS

Deposit Features: Typical grades range from 3 to 14 percent zinc and usually lesser amounts of lead. The zinc/lead ratio is frequently 2:1 or less. Small amounts of copper and gold are nearly always present. Silver values are commonly in the 1-9 percent range. The ore minerals most often found are sphalerite, galena, pyrrhotite, magnetite, chalcopyrite, and arsenopyrite. The accessory minerals that make up the skarn are manganoan hedenbergite, andraditic garnet, spessartine, bustamite and rhodonite. The presence of manganese-bearing minerals is distinctive to this type of skarn. Those deposits that form near contacts with batholithic intrusives tend to be smaller than other types of zinc skarn. The largest are those found near intrusive stocks. As a group, zinc-lead skarns range from 300,000 tons to 20 million tons in size.

Alteration: Intense but localized hydrothermal alteration of the intrusive causes development of epidote, and manganese-bearing pyroxenes and garnets similar to those found in the skarn portion. Alteration of the skarn shows up as development of manganerous actinolite, ilvaite, chlorite, and rhodochrosite.

Ore Controls: The skarn in most deposits occurs somewhat distal (300 feet or more) to the intrusive. Localization appears to occur along structural and lithologic contacts in the host rocks and/or along faults.

Weathering: A gossan may develop above the skarn zone if topography and past climatic conditions were favorable. Iron oxides and staining of the nearby rocks would be the most obvious indicator.

Geochemical Expression: Above or immediately downslope from the skarn, anomalous amounts of silver, arsenic, beryllium, cobalt, copper, fluorine, lead, tin, and tungsten should be present. Because of its mobility, anomalous amounts of zinc will show up in the peripheral area of the skarn.

Geophysical Expression: Very little information is available on the signature this type of mineralization may have. Various electrical and/or magnetic methods might be applied but the response would depend upon the amount of sulfide minerals and magnetite present in the skarn, and the amount of cover.

Associated Mineralization: This model type is frequently associated with copper skarn. A zoning of the major silicates and sulfides minerals is frequently displayed. The deeper and central part of the skarns commonly exhibit garnet, magnetite, and chalcopyrite. Higher and laterally in the skarn this assemblage may change to pyroxene and sphalerite. The outermost zone may contain mainly galena.

Deposit Examples:	References:
Aravaipa (AZ)	Reiter, 1981
Washington Camp (AZ)	Simon, 1972
Cooney Zinc (CA)	Samson and Tucker, 1940
Mineral King (CA)	Knopf and Thelen, 1905
South Mountain (ID)	Sorenson, 1927
Paymaster (NV)	Gulbrandes and Gielow, 1960
Black Hawk (NM)	Mosier, 1983d
Empire (NM)	Hernon and Jones, 1968
Ground Hog (NM)	Hernon and Jones, 1968
Linchburg (NM)	Titley, 1961

Deposit Type: TUNGSTEN SKARN

Subtype: It has been proposed that tungsten skarns be classified as either reduced or oxidized on the basis of host rock and depth of formation. In comparing actual deposits there is considerable overlap and the outward appearance of both subtypes is not that different.

Synonym Name: Contact metamorphic, contact metasomatic, pyrometasomatic, or tungsten tactite.

Description: Scheelite mixed with calc-silicate minerals that have formed in calcareous sediments at or near the contact with an intruding magma.

GEOLOGIC FEATURES

Regional Setting: Most deposits are related to the continental portions that were in late to postorogenic stages of activity.

Structural Features: This type of mineralization is related to stocks and batholiths that have intruded calcareous sediments. The intrusive is typical a coarse-grained porphyritic granodiorite or quartz monzonite of mid-Paleozoic to late Cretaceous age. No predominant type or orientation of faults or lineaments have been found associated with these deposits.

Stratigraphic and Lithologic Characteristics: Skarns most frequently occur in argillaceous carbonate rocks and intercalated carbonate-pelite or carbonate-volcanic sequences. It is common to find the skarn occurring in the lowest carbonate bed of a stratigraphic sequence. Age of the host rock can range from Precambrian to Triassic. The intrusive action will generally alter the sediments to hornfels and/or marble.

MINERAL CHARACTERISTICS

Deposit Features: Skarn is most often found at or near the intrusive contact in stratiform structures or pods. Tungsten content is very erratic with most deposits ranging in grade from 0.3 to 1.5 percent tungsten oxide. Although a few de- posits may contain up to 25 million tons of ore, the majority are much smaller in size, having from 55,000 tons to 1 million tons. The main ore mineral is scheelite that always carries small amounts of molybdenum. Accessory minerals are chalcopyrite, pyrrhotite, pyrite, magnetite, sphalerite, arsenopyrite and bismuthinite. Copper content may be high enough in some deposits to be considered a co-product. The skarn composition will vary somewhat depending on the host rock. Most contain mixtures of mainly pyroxene and garnet with lesser amounts of epidote, wollastonite, sphene, apatite, and actinolite.

Alteration: Generally, very little alteration of the intrusive takes place. Nearly all alteration is evident in the intruded rocks where diopside, hedenbergite, grossular and andradite garnets are formed. Outside of the skarn may lie a barren wollastonite zone and beyond that, marble.

Ore Controls: The structure ot the host rocks, the dip of the bedding relative to the intrusive contact, jointing and/or fractures of the intrusive and the configuration of the intrusive contact are important ore controls. Most favorable situations are where the intrusive intersects the limb of an anticline of favorable host rocks or a fold in the host rocks plunges steeply towards the intrusive contact.

Weathering: Oxidation of some of the iron-bearing minerals will result in staining of nearby rocks. The amount or degree will depend on past climatic conditions, topography, and amount of skarn exposed to weathering.

Geochemical Expression: Anomalous amounts of tungsten, copper, molybdenum, bismuth, beryllium, tin, fluorine, and niobium should be tested for near granitic contacts with calcareous beds.

Geophysical Expression: Magnetic and electrical methods could be useful, but their success would depend on how much magnetite, pyrite, and pyrrhotite is in the skarn. Regional aeromagnetics might outline buried plutons as magnetic highs which would be significant in areas where favorable carbonate rock are known to exist.

Associated Mineralization: Occasionally, tin and zinc skarn are associated with the tungsten mineralization but this is not commonly found.

Deposit Examples:	References:
Black Rock (CA)	Rinehart and Ross, 1956
Pine Creek (CA)	Newberry, 1982
Strawberry (CA)	Nokleberg, 1981
Tungsten Jim (ID)	Sigurdson, 1974
Yellow Pine (ID)	Cooper, 1951
Calvert (MT)	Geach, 1972
Lost Creek (MT)	Collins, 1977
Mills City (NV)	Kerr, 1934
Nevada-Scheelite (NV)	Geehan and Trengrove, 1950
Osgood Range (NV)	Taylor and O'Neil, 1977
Tem Piute (NV)	Buseck, 1967
Iron Mountain (NM)	Jahns, 1944
Milford (UT)	Hobbs, 1945

Deposit Type: VOLCANOGENIC MASSIVE SULFIDES

Subtype: Cyprus

Synonym: Cupreous pyrite type

Description: Lenses of massive pyrite and copper minerals in mafic-ultramafic rocks. Name derived from the deposits on the island of Cyprus.

GEOLOGIC FEATURES

Regional Setting: These deposits are found along the orogenic belts of continental margins. Their position is believed to have resulted from seafloor spreading that subsequently uplifted and thrust fragments of the crust containing the deposits onto the continents during plate convergence.

Structural Features: Most of the major deposits are associated with pillow lavas or with volcanic breccias. Also, there seems to be an affinity with tensional graben-type faulting.

Stratigraphic and Lithologic Characteristics: Mineralization is most often found in the lower mafic volcanics and diabase dike complexes of ophiolites. Very few deposits that occur in clastic or pyroclastic strata are present in the volcanic sequence. Pelagic sedimentary rocks may cover the volcanic series. The age of these deposits range from late Precambrian to Mesozoic with most dated at Ordovician-Devonian or Cretaceous.

MINERAL CHARACTERISTICS

Deposit Features: The main mineralization is pyrite and chalcopyrite and less commonly pyrrhotite. Minor amounts of marcasite and sphalerite may be present. Galena and bornite are rarely present. The gangue minerals are typically quartz, chlorite, carbonate, and gypsum. The sulfides occur most frequently as concordant tabular, lenticular, or saucer-shaped bodies in pillow lavas. A pipe or funnel-shaped stockwork zone of veins and copper dissemination may occur beneath the massive sulfide portion. Some deposit exhibit an iron-rich capping of ochre. Chert and manganese oxides may cap the ochre. Size of the deposits can range from a few thousand tons to 20 million tons but 2 to 5 million tons is more usual. Copper values commonly range from 0.5 percent to 4 percent, zinc from 0.1 to 3 percent, and gold and silver 0.1 to 2 ounces per ton.

Alteration: Mafic rocks are altered to zeolite and green-schist facies along with variable chloritization and/or silicification. Most of alteration is confined to the stockwork zone if present.

Ore Controls: The pillow basalt structure and brecciation of mafic volcanics appear to strongly influence the ore location. Pre-ore faulting and related fractures is important in some deposits.

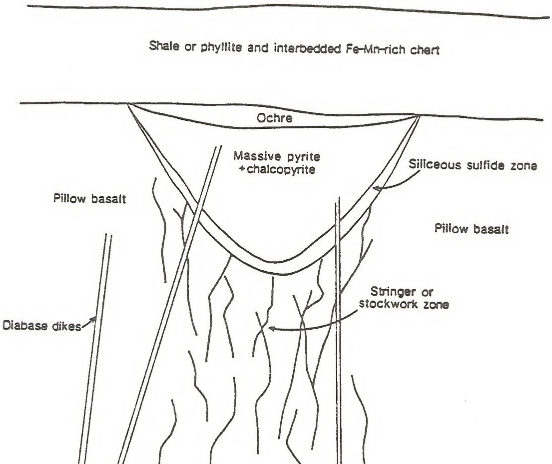
Weathering: Under most weathering conditions, a gossan will form above a massive sulfide deposit if exposed to weathering. The appearance of the gossan depends on the original sulfide mineralization, nature of the host rock, and the climatic conditions. In any case it will probably be some shade of tan or brown. Development of the gossan often mimics the size and size of the underlying massive sulfide bodies.

Geochemical Expression: Pillow lavas near points of mineralizations will frequently have anomalous amounts of zinc and cobalt and be depleted in copper. Lavas in the peripheral areas often have anomalous amounts of iron, sulfur, copper, zinc, and cobalt. Manganese and iron-rich cherts nearby are indicators of hydrothermal discharge and possible sulfide mineralization. Gold may be found in nearby stream sediments.

Geophysical Expression: Aeromagnetic surveys may be useful in locating volcanic centers that are often reflected as a negative anomaly. Massive sulfide bodies would reflect as positive anomalies, but the response would depend on the amount of pyrrhotite present, size and shape of the bodies, and amount of cover.

Associated Mineralization: None are known to occur with this type of mineralization, but occasionally chalcopyrite is subordinate to sphalerite. The zinc has an erratic distribution and may be only locally abundant.

Deposit Examples:	References:
Rua Cove (AK)	Singer and Mosier, 1983
Island Mountain (CA)	Stinson, 1957
Big Mike (NV)	Rye et al., 1984
Turner-Albright (OR)	Shenon, 1933



Idealized cross-section of a Cyprus type volcanogenic massive sulfide deposit (from USGS Open File Report 83-423)

Deposit Type: VOLCANOGENIC MASSIVE SULFIDES

Subtype: Polymetallic

Synonym: Lead-zinc-copper-silver type

Description: Lenticular to tabular bodies of massive pyrite with predominant lead, zinc, and copper minerals in felsic volcanic rocks.

GEOLOGIC FEATURES

Regional Setting: This type forms mainly in eugeosynclinal troughs bordering volcanic domes and cratonic areas. These are late stage activities believed to have resulted from seafloor spreading.

Structural Features: Usually tensional graben-type faulting is present. In most deposits, the rocks are medium to highly metamorphosed disguising somewhat the original structure and altering the character and texture of the rocks.

Stratigraphic and Lithologic Characteristics: The enclosing rocks are commonly thin volcanic sequences that grade upward from mafic, to intermediate, to felsic tholeiitic basalt. Silici-alkalic lava, and pyroclastics are found associated with most deposits. Intercalated with the volcanics are sedimentary rocks, such as limestones, bedded sulfates, minor iron formations, graphic schists, and ferrugenous chert. The age of these deposits range from late Proterozoic to Tertiary. The younger deposits are generally smaller in size than the older deposits.

MINERAL CHARACTERISTICS

Deposit Features: Mineralization is generally stratabound, irregular and lenticular to tabular in form. Pyrite is the dominant sulfide in mildly metamorphosed areas while pyrrhotite occurs when highly metamorphosed. Lead occurs as galena, zinc as marmatitic sphalerite, and copper as chalcopyrite. Lead-rich ores carry important amounts of silver with lesser amounts of gold. Quartz is the most common gangue mineral, in fact mineralization generally is more intense in the more silicic host rock. Lead content commonly ranges from 1 to 3 percent, zinc 3 to 8 percent; and copper 0.5 to 2.0 percent. Silver content is usually 1 to 3 ounces per ton. These deposits are relatively small, ranging from 100,000 tons to 1.5 million tons.

Alteration: The more intensely altered areas are generally at the bottom or "root zone" of mineralization. They may consist of chloritization, sericitization, silicification, and tourmalinization. Areas lateral to the deposit are commonly chloritized and sericitized.

Ore Controls: Mineral zoning is common with lead at the top and grading downward into zinc and copper. Mineralization contacts are frequently sharp in the upper areas of the deposit with veins and veinlets developing in the lower part or bottom of the deposit. The ore minerals commonly grade laterally into the host rock resulting in an iron sulfide halo several times larger than that of the ore body. The iron sulfide content usually increases toward the ore body. The lenses of mineralization rarely occur alone but are found in clusters or in boudin-form.

Weathering: If exposed, gossan will generally develop. Most often it is lenticular in shape and yellow, red or brown in color. The appearance depends on the original sulfide mineralization, nature of the host rocks, and climatic conditions.

Geochemical Expression: Lead is frequently anomalously high in the gossan whereas zinc and copper values are usually not present. Detectable amounts of gold in the gossan are indicative of polymetallics beneath the capping rather than barren iron sulfides. The halo of iron sulfides surrounding many deposits is usually anomalously low in copper, lead, zinc, gold, and silver values.

Geophysical Expression: Electromagnetic methods are especially suited to detecting this type of deposit because of the high pyrite and/or pyrrhotite content of the ore. Detection depends on the size and shape of the ore body, and the amount and type of cover. Aeromagnetics might be useful in locating felsic volcanic centers that would be indicated by negative anomalies. Massive sulfide deposits under favorable conditions would be indicated by positive anomalies.

Associated Mineralization: In a few deposits gold-quartz veins are known to occur beneath but at a considerable distance from massive sulfide deposits of this type.

Deposit Examples:	References:
*Arctic (AK)	Mosier et al., 1983
*Beatson (AK)	Bateman, 1924
*Greens Creek (AK)	Mosier et al., 1983
*Orange Point (AK)	Mosier et al., 1983
*Antler (AZ)	Anderson and Guilbert, 1979
*Binghampton (AZ)	Anderson and Guilbert, 1979
*Bruce (AZ)	Anderson and Guilbert, 1979
Iron King (AZ)	Gilmore and Still, 1968
Afterthought (CA)	Albers and Robertson, 1961
Big Bend (CA)	Eric, 1948
*Blue Ledge (CA)	Mosier et al., 1983
Blue Moon (CA)	Heyl and Cox, 1948
Bully Hill-Rising Star (CA)	Albers and Robertson, 1961
Copper Hill (CA)	Mosier et al., 1983
*Gray Eagle (CA)	Mosier et al., 1983
Keystone-Union (CA)	Heyl, 1948(a)
Newton (CA)	Heyl and Eric, 1948
North Keystone (CA)	Heyl, 1948(a)
Penn (CA)	Heyl et al., 1948
Quail Hill (CA)	Heyl, 1948(b)
Spencerville (CA)	Mosier et al., 1983
*Chestatee (GA)	Mosier et al., 1983
*Bald Mountain (ME)	Mosier et al., 1983
*Barrett (ME)	Young, 1963
*Big Hill (ME)	Young, 1963
*Deer Isle (ME)	Mosier et al., 1983
*Emerson (ME)	Mosier et al., 1983
*Tapley (ME)	Earl, 1950
*Davis (MS)	Mosier et al., 1983
*Pecos (NM)	Mosier et al., 1983
*Flambeau (WI)	Mosier et al., 1983

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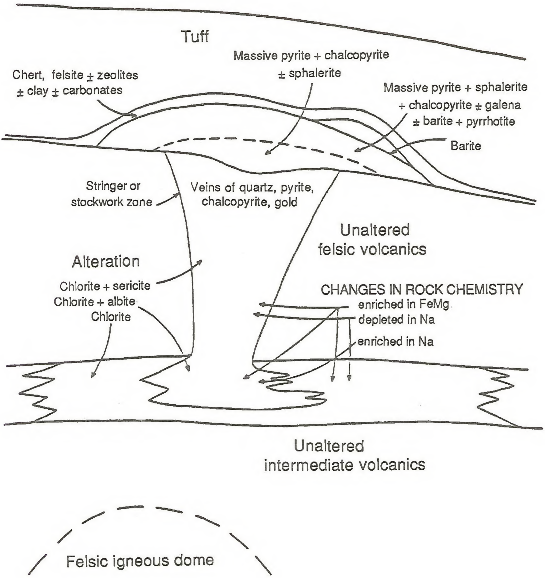
*Geologic information is insufficient to classify as deposit type, may be either #3.01B or #3.01C.



Idealized cross-section of a polymetallic type of a volcanogentic massive sulfide deposit (from USGS Open File Report 83-423)

Deposit Type: VOLCANOGENIC MASSIVE SULFIDES

Subtype: Zinc-copper

Synonym: Primitive or Kuroko type

Description: Lenticular deposits of zinc, copper, and massive iron sulfides associated with Precambrian and early Paleozoic marine volcanic rocks.

GEOLOGIC FEATURES

Regional Setting: These deposits are associated with very large scale eugeosynclinal volcanism occurring in mainly very early stage of a tectonic cycle.

Structural Features: No distinctive type of structural features are known to be associated with these deposits. General high-angle normal faults are nearby as expected in a synclinal environment.

Stratigraphic and Lithologic Characteristics: Most occurrences are found in a thick sequence of volcanic rocks several tens of thousand feet thick. Mafic rocks made up the bottom of the pile with a gradation to intermediate and felsic types near the top. Sedimentary iron formations, ferruginous cherts, and volcanogenic iron and silica-rich graywackes are frequently intercalated with the volcanic layers. The age of the majority of deposits is late Precambrian to Devonian, but a very few deposits are dated as late Mesozoic and early Cenozoic. The larger deposits are generally the oldest.

MINERAL CHARACTERISTICS

Deposit Features: Deposits of this type are frequently in irregular lenticular or tabular shapes. Copper, zinc, and gold are the primary elements dispersed in pyrite or pyrrhotite. They take on a massive or layered appearance depending upon the sulfide content. Mineralization is frequently found associated with the more silicic volcanic rocks. Ore minerals are most often sphalerite and chalcopyrite and rarely galena. More gold is found in copper-rich deposits whereas high silver is associated with zinc-rich deposits. Most of the known deposits range in size from 100,000 to 20,000,000 tons. Copper grade ranges from 0.40 to 3.50 percent; zinc, 2 to 9 percent. Gold values are commonly in the 0.003 to 0.07 ounces per ton range, and silver ranges from 0.35 to 3.00 ounces per ton.

Alteration: At the base of the deposits alteration is usually more intense. It consists of chloritization, sericitization, silicification, and tourmalinization. The sides of the deposit may have chlorite and sericite. Some of these products may have resulted from regional metamorphism rather than alteration.

Ore Controls: A predominate number of deposits are located near centers of felsic volcanism such as felsic domes, calderas, and volcanic necks. Rocks may be locally brecciated near the centers. Mineral zoning is sometimes apparent with zinc at or near the top of the deposit and grading downward toward increasing copper. The upper contact of these deposits is sharp whereas below the main mineralized, veins may occur. A halo of iron sulfides is often found around the deposit.

Weathering: If past weathering conditions were favorable, a gossan will most likely form over the deposits. The appearance of the gossan will depend on the original sulfide minerals, the host rock, and the climatic conditions. The most common colors are various shades of brown and dark red.

Geochemical Expression: Detectable amounts of gold in the gossan are generally indicative of base metals beneath the gossan. Copper and zinc usually are depleted in the gossan area, but sometimes are found as a halo region along with anomalous amounts of gold and silver.

Geophysical Expression: Electromagnetic methods would probably be the most discriminating to use, but success would depend on depth, type of cover, shape of the deposit, and amount of iron sulfide present. Aeromagnetics might locate felsic centers, often reflected as negative anomalies, whereas sulfide bodies could show up as positive anomalies if enough pyrrhotite is present.

Associated Mineralization: Gold in quartz veins is sometimes found in the root zone beneath deposits of this type.

Deposit Examples:	References:
*Artic (AK)	Mosier et al., 1983
*Beatson (AK)	Mosier et al., 1983
*Greens Creek (AK)	Mosier et al., 1983
*Orange Point (AK)	Mosier et al., 1983
*Antler (AZ)	Anderson and Guilbert, 1979
*Binghampton (AZ)	Anderson and Guilbert, 1979
*Bruce (AZ)	Anderson and Guilbert, 1979
United Verde (AZ)	Anderson and Creasey, 1958
Balaklala (CA)	Kinkel et al., 1956
*Blue Ledge (CA)	Mosier et al., 1983
Early Bird (CA)	Kinkel et al., 1956
*Gray Eagle (CA)	Mosier et al., 1983
Iron Mountain (CA)	Kinkel et al., 1956
Keystone (CA)	Kinkel et al., 1956
Mammoth (CA)	Mosier et al., 1983
Shasta King (CA)	Kinkel et al., 1956
Stowell (CA)	Kinkel et al., 1956
*Chestatee (GA)	Mosier et al., 1983
*Bald Mountain (ME)	Mosier et al., 1983
*Barrett (ME)	Young, 1963
*Big Hill (ME)	Young, 1963
*Deer Isle (ME)	Mosier et al., 1983
*Emerson (ME)	Mosier et al., 1983
*Tapley (ME)	Earl, 1950
*Davis (MS)	Mosier et al., 1983
*Pecos (NM)	Mosier et al., 1983
*Flambeau (WI)	Schwenk, 1977

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*Geologic information is insufficient to classify as to deposit type; may be either #3.01B or #3.01C.

Deposit Type: VOLCANOGENIC MANGANESE

Synonym: Ophiolitic manganese

Description: Massive lenses of manganese oxide, carbonate, and silicate in intercalated sequences of volcanic and sedimentary rocks.

GEOLOGIC FEATURES

Regional Setting: Most deposits of this type are believed to have formed in an eugeosynclinal subduction complex. More explicitly, they are thought to have resulted from seafloor hot spring systems that may have formed in marginal ocean basins, at the base of island arcs, oceanic ridges, or at the base of oceanic islands.

Structural Features: Regional rocks are commonly basaltic lava that show pillow structure indicative of underwater deposition.

Stratigraphic and Lithologic Characteristics: Host rocks are usually thin-bedded red radiolarian chert intercalcated with basalt, greenstones, tuff, and graywacke. Varying amounts of metamorphism is nearly always present distorting the bedding features and altering the associated minerals. Age of the enclosing rocks varies from Cambrian to Pliocene.

MINERAL CHARACTERISTICS

Deposit Features: Typically, the ore occurs as massive black lenses of poorly crystalline or amorphous manganese oxides, carbonates, and manganiferous chert. The lenses are generally circular or elliptical in shape having a thickness from a few inches to 60 or 90 feet and a length extending 650 to 900 feet. The ore bodies can range from less than 3,000 to several million tons in size. It is not uncommon to find two, three, or more lenses stacked more or less above one another and separated by 5 to 30 feet of thin bedded chert. The enclosing chert is frequently red jasper but may range in color from white to green or brown. Beneath the cherts, basalts or greenstones are usually found. Ore minerals are frequently a mixture of rhodochrosite, pyrolusite, hausmannite, braunite, rhodonite, bementite, neotocite, and inesite. In the more massive portions of the lenses, 30 to 50 percent manganese may be found. At the edges of the lenses, the silica content increases to form manganiferous chert.

Alteration: The originally deposited minerals are thought to have been manganiferous opal, carbonate, and oxides. Through later supergene and metamorphic activity, these minerals were altered to the present mineral suite. Alteration of the surrounding basalts to greenstones is common along with silification and the injection of ferriferous solutions.

Ore Controls: Faults and fractures in permeable sequences of beds in the sub-sea floor allowed hydrothermal solutions to circulate. Manganese was deposited at the seafloor-seawater interface as the result of reduction and oxidation of the ascending solutions. Later supergene enrichment probably upgraded the manganese content.

Weathering: Under most weathering conditions secondary manganese oxide minerals of birnessite, pyrolusite, todorokite, and amorphous manganese oxide may form.

Geochemical Expression: Anomalous amounts of barium, lithium, rubidium, zinc, lead, and copper can be expected near deposits of this type.

Geophysical Expression: None have been documented.

Associated Mineralization: None definitely identified. It has been speculated that the mode of deposition might cause deposition of iron-rich sulfides at depth beneath the manganese accumulations.

Deposit Examples:	References:
Blue Jay (CA)	Crerar et al., 1982
Buckeye (CA)	Taliaferro and Hudson, 1943
Cummings (CA)	Trask et al., 1943
Fabian (CA)	Trask et al., 1943
Foster Mountain (CA)	Trask et al., 1943
Ladd (CA)	Taliaferro and Hudson, 1943
Liberty (CA)	Trask et al., 1943
South Thomas (CA)	Crerar et al., 1982
Thatcher Creek (CA)	Trask et al., 1943
Thomas (CA)	Trask et al., 1943
Welch (CA)	Trask et al., 1943
Black Diablo (NV)	Needham and Trengrove, 1950
Beaver Falls (WA)	Sorem and Gunn, 1967
Brown Mule (WA)	Park, 1942
Cresent (WA)	Park, 1942
Dosewallipo (WA)	Sorem and Gunn, 1967
Hurricane (WA)	Park, 1942
Littleton (WA)	Sorem and Gunn, 1967
Skunk Creek (WA)	Park, 1942

Deposit Type: PRECIOUS AND BASE METAL REPLACEMENT

Subtype: Limestone replacement

Synonym: Manto or metasomatic deposits

Description: A hydrothermal, epigenetic, sulfide mineral deposit that commonly replaces selective beds of limestone, dolomite, or other soluble rock.

GEOLOGIC FEATURES

Regional Setting: Most deposits have formed in a plutonic environment spatially related to batholiths. The carbonate host rocks commonly occur in broad sedimentary basins and are moderately deformed.

Structural Features: Thin bedded and brittle rock sequences that are folded, fractured, and faulted are especially favorable because they present channelways for ascending mineral solutions. The majority of the deposits are found near the borders of batholiths in the contact zones of satellite plutons, or in roof pendants in plutons.

Stratigraphic and Lithologic Characteristics: The associated intrusives are predominantly calc-alkaline of the granodiorite or quartz monzonite type. They frequently are equigranular and contain late dikes and quartz veining. Most, but not all, are late Mesozoic to early Cenozoic in age. The sedimentary host rocks are chiefly limestones, but can also be dolomite and shales. In some deposits only the more pure limestone is replaced while in others impure carbonates and/or siliceous clastic beds are favored. Sometimes a particular layer in an otherwise indistinguishable sequence of rock is the favorable replacement bed. The sediments can be any age but predominantly are Paleozoic.

MINERAL CHARACTERISTICS

Deposit Features: The deposits may occur in many forms, but are usually irregular or podlike in shape. Occasionally, ribbonlike or blanketlike deposits will form along selective layers or beds. A great variety of ore minerals can occur in this type of deposit but never more than two or three at one time. Some of these are galena, sphalerite, argentite, tetrahedrite, enargite, chalcopyrite, proustite, pyrargyrite, jamesonite, bournonite, tennantite, jordanite, stephanite, polybasite, sylvanite, calaverite, native gold, bismuthinite, and rhodochrosite. Accessory minerals can be pyrite, marcasite, barite, quartz, arsenopyrite, garnet, wollastonite, fluorite, and calcite.

Deposits of this type range widely in size from 250,000 tons to 15 million tons. For those deposits containing predominantly copper and/or gold, the grade is generally high but extremely variable. Gold frequently grades from one to two ounces/ton while copper often ranges from 5 to 20 percent. Deposits containing lead and zinc often carry minor but important amounts of gold and silver.

Alteration: Very little alteration is generally evident in the intrusive rock and when present is very narrow and at the contact. Alteration of carbonates is evident by bleaching, recrystallization to marble, and development of some calc-silicate minerals such as scapolite, idocrase, or tremolite. Alteration is usually gradational away from the intrusive contact.

Ore Controls: The configuration of the intrusive and the attitude of the host rocks are extremely important in emplacement of the deposits. One of the more favorable situations is where the intrusive intersects the limb of an anticline or fold of favorable host rocks thereby allowing mineralizing solutions to travel upward along bedding planes. Joints and fractures in the host and/or intrusive also aids migration of the fluids and induces chemical reactions where possible.

Weathering: No unique weathering features are generally present. Iron minerals may oxidize to ocherous masses containing oxides of copper, lead, zinc, and silver.

Geochemical Expression: Many deposits exhibit a zonal arrangement of anomalous copper at the center followed by lead-silver, and a zinc and manganese zone at the fringes. Other elements that are frequently associated with this type of deposit are bismuth, arsenic, fluorine, and molybdenum.

Geophysical Expression: Generally, most geophysical methods will not detect these deposits directly because of the small target size. Regional aeromagnetics have been used successfully in detecting buried plutons in areas where favorable carbonate rocks are known to exist. These usually appear as magnetic highs.

Associated Mineralization: Some precious and base metals occur in veins in and/or near the contact zone.

Deposit Examples:	References:
Kennecott, AK	Bateman, 1942
Christmas, AZ	Willden, 1964
Bisbee, AZ	Hogue and Wilson, 1951
Pima, AZ	Irvin, 1959
Gilman, CO	Tweto and Lovering, 1947
Leadville, CO	Emmons et al., 1927
Ouray, CO	Burbank, 1968
Phillipsburg, MT	Prinz, 1961
Eureka, NV	Nolan and Hunt, 1968
Homestake, SD	McLaughlin, 1931
Bingham, UT	Rubright and Hart, 1968
Park City, UT	Barnes and Simos, 1968
Tintic, UT	Morris and Lovering, 1979

Deposit Type: CARBONATE-HOSTED GOLD

Subtype: Disseminated gold

Synonym: Carlin type or colloidal gold

Description: Very fine colloidal gold and sulfides disseminated in carbonaceous carbonate rocks.

GEOLOGIC FEATURES

Regional Setting: Eugeosynclinal carbonates deposited in a somewhat reducing environment that later becomes tectonically active.

Structural Features: Moderate regional folding of the sediments is common with many high angle normal faults. Dikes and small plutons are nearly always found in the immediate vicinity.

Stratigraphic and Lithologic Features: Favorable host rocks are limestones, dolomites, and siltstones containing organic carbon and pyrite. Age of the host rocks does not seem to be a critical favor. The associated intrusives range from quartz diorite to quartz monzonite and are frequently porphyritic. They are mainly Tertiary in age but can range to early Cretaceous.

MINERAL CHARACTERISTICS

Deposit Features: Microscopic and submicroscopic gold occurs as tiny seams and veinlets with quartz. It is also found filling fine fractures in pyrite and to a lesser extent as precipitations on organic carbon. The gold particles range from 10 to 0.5 micron in size and commonly grade from 0.03 to 0.30 ounces/ton. The deposits may range in size from two million to 25 million tons. Most of the ore deposits are stratiform and lie in a zonal pattern that may encircle chimney areas of silification. The ore frequently exhibits a spatial relation to the intersection of high-angle faults although the faults themselves are rarely mineralized. Most of the deposits have oxidized and unoxidized ores. Oxidized ores contain iron oxides, clays, microscopic quartz, arsenic, antimony, and mercury sulfides. Unoxidized ores are higher in pyrite, organic carbon, arsenic sulfides, and barite.

Alteration: Hydrothermal solutions usually bleach and leach large areas. Both the host rocks and the associated igneous rocks were affected, but sediments show the greatest change. Widespread replacement of carbonate by silica is the most common exhibited feature. In the unoxidized ore zones, jasperoid, quartz, illite, kaolinite, and calcite are found. The oxidized ores exhibit kaolinite, montmorillonite, illite, jarosite, and alunite.

Ore Controls: The principal control features were tectonic folding and fracturing of brittle sediments. The hydrothermal solutions selectively replaced carbonaceous carbonate beds adjacent to high angle faults and regional thrust faults.

Weathering: No particular distinguishing features are found at most deposits. The widespread alteration usually found may change selective beds or layers to light reddish gray or tan. Light brown to reddish brown stained jasperoid is also usually present.

Geochemical Expression: Most deposits exhibit anomalous amounts of arsenic (400 ppm), antimony (100 ppm), mercury (25 ppm), and thallium (50 ppm). Barite is commonly present along with higher than normal amounts of molybdenum, tungsten, and fluorine.

Geophysical Expression: No distinctive pattern has been recognized over this type of deposit. The amount of disseminated pyrite in the unoxidized ore zone is low enough that electrical methods probably could not detect the mineralization.

Associated Mineralization: Small prospects of silver, lead, zinc, copper, and mercury sometimes occur in the near vicinity.

Deposit Examples:	References:
Alligator Ridge (NV)	Stanford, 1984
Carlin (NV)	Hausen and Kerr, 1968
Cortez (NV)	Wells et al., 1969
Getchell (NV)	Joralemon, 1951
Gold Quarry (NV)	Hausen and Kerr, 1968
Jerritt Canyon (NV)	Jackson, 1982a
Maggie Creek (NV)	Hausen and Kerr, 1968
Northumberland (NV)	Kral, 1951
Pinson (NV)	Jackson, 1982b
Preble (NV)	Jackson, 1982b
Santa Fe (NV)	Clark, 1922
Mecur (UT)	Butler et al., 1920

Deposit Type: LOW-SULFIDE GOLD-QUARTZ VEINS

Synonym: Mother Lode type

Description: Gold in massive but discontinuous quartz veins and lodes mainly in regionally metamorphosed sediments and volcanics

GEOLOGIC FEATURES

Regional Setting: Deposits are found along the mobile belts of the continental margins, namely the western foothills of the central Sierra Nevada Mountains (Mother Lode region) and the southeastern front of the Appalachian Mountains (Piedmont region).

Structural Features: Orogenic stresses caused complex folding and overturning of beds with accompanying fractures and faulting. Much of the mineralization is associated with thrust faults of small displacement; normal faults are also present. Shear zones along northwest or northeast directions have created secondary tension cracks.

Stratigraphic and Lithologic Characteristics: The principal rocks are slates, schists, greenstones, quartzites, and gneisses. Very few of the original Precambrian to Tertiary sediments have escaped regional metamorphism. Age of the rocks ranges from early Paleozoic to mid-Mesozoic. Later intrusions of peridotite, diabase, gabbro, granodiorite, quartz diorite, and small dikes of various types have invaded the metamorphosed sediments. Great belts of peridotite have been altered to serpentine that is partly associated but not exclusively with the mineralization.

MINERAL CHARACTERISTICS

Deposit Features: The gold deposits occur either as quartz veins or as bodies of mineralized country rock. The quartz veins generally occur as systems of parallel or acutely intersecting veins. Not many can be traced for more than a few thousand feet. They cut the enclosing rocks at an acute angle in both strike and dip. The veins swell and pinch abruptly filling fissures that were formed mainly from reverse faulting. Banding or ribboning of the quartz is common when the veins traverse schist or slate.

The ore bodies of mineralized country occur either adjacent to quartz veins or in broad zones of fissuring. Many of these ore bodies formed either in the footwall or hanging wall of a large thick barren quartz vein. The gold in both types of deposits is dispersed as small blebs and/or veinlets and ranges in grade from 5 to 40 grams per ton. Ore bodies commonly vary from 15,000 to

1.5 million tons in size. Mineralization is usually accompanied by ankerite, sericite, fine-grained pyrite, galena, sphalerite, and arsenopyrite. Galena and petzite are indicators of good ore.

Alteration: Carbonization (or ankeritization) is the chief alteration feature and is present in all rocks regardless of type. Ankeritized serpentine takes on a pale green color due to the formation of a chromium potassium mica (mariposite). Sericite, albite, pyrite, and arsenopyrite are often formed by the alteration of the wall rocks.

Ore Controls: Mineralization appears to have been controlled by faulting and joints. The country rock had little effect on deposition although slates seem to be more favorable than greenstones, and serpentine is almost absent of gold mineralization. In general, the more brittle rocks are the most favorable.

Weathering: No distinctive features have been noted in the mineralized areas. Some of the early rich placers developed above and downslope from mineralized zones as the result of weathering of the country rock and concentrating the gold in place.

Geochemical Expression: Arsenic has been found to be the most persistent pathfinder for this type of mineralization. Other elements are less reliable. In the southern Piedmont area, there is a general regional zonal arrangement. Gold is found nearest the magmatic source and then grades outward to a zone characterized by chalcopyrite, pyrite, and pyrrhotite and then a zone of galena, sphalerite, and barite.

Geophysical Expression: No specific signature is known to be connected with this type of mineralization. Some success has been obtained using aeromagnetics to map ultrabasic rock units in the Mother Lode area, but no correlation was found between magnetic patterns and known mineral deposits.

Associated Mineralization: Some massive sulfide copper deposits are found in the general region. Nearly all of the deposits contain small amounts of associated copper, silver, lead, and zinc, but may be too low a grade to recover.

Deposit Examples:	References:
Dutch Bend, AL	Pardee and Clark, 1948
Hog Mtn., AL	Pardee and Clark, 1948
Angels Camp, CA	Eric et al., 1955
Carson Hill, CA	Knopf, 1929
Grass Valley, CA	Johnston, 1940
Jackson-Plymouth, CA	Knopf, 1929
Jamestown, CA	Eric et al., 1955
Soulsbyville, CA	Knopf, 1929
Barlow, GA	Pardee and Clark, 1948
Battle Branch, GA	Pardee and Clark, 1948
Findley Ridge, GA	Pardee and Clark, 1948
Coggins, NC	Pardee and Clark, 1948
Gold Hill, NC	Pardee and Clark, 1948
Howie, NC	Pardee and Clark, 1948
Lewis, NC	Pardee and Clark, 1948
Parker, NC	Pardee and Clark, 1948
Phoenix, NC	Pardee and Clark, 1948
Rudisil, NC	Pardee and Clark, 1948
Bar Kat, SC	Pardee and Clark, 1948
Brewer, SC	Pardee and Clark, 1948
Dorn, SC	Pardee and Clark, 1948
Haile, SC	Pardee and Clark, 1948
Franklin, VA	Pardee and Clark, 1948
Melville, VA	Pardee and Clark, 1948

Deposit Type: EPITHERMAL GOLD AND SILVER

Subtype: Quartz-adularia

Synonym: Precious and base-metal veins; Comstock epithermal veins

Description: Precious metals in vuggy quartz and adularia veins with abundant pyrite and arsenopyrite and lesser amounts of galena and sphalerite.

GEOLOGIC FEATURES

Regional Setting: Most of the major deposits are associated with orogenic activities found in the subduction zone along continental margins and to a lesser extent with back-arc basins.

Structural Features: The most important districts occur where there are strong, persistent fracture systems such as Basin and Range-type faults, caldera ring fracture zones, caldera-related graben structures, or complex faulting or domal areas. The structures may be any age, but some of the more productive deposits are related to Tertiary age thermal events.

Stratigraphic and Lithologic Characteristics: There is generally no favorable nor preferential rock type in most deposits. Deposition is mainly related to brittleness of the related rocks when deformed. Brittle rocks form more cavities and solution paths when folded or faulted than more pliable units thereby enhancing deposition. Carbonate rocks are occasionally more favorable for mineralization depending on the character of the mineralizing solutions.

MINERAL CHARACTERISTICS

Deposit Features: The majority of the deposits occur as veins, stockworks, and replacements in volcanic rocks and as replacements and veins in sedimentary sequences. The ore frequently exhibits colloform banding, crustifications, open-space filling, and comb structure. Mineralization can take the form of native gold or silver; tellurides; and sulfides of arsenic, antimony, silver, mercury, and base-metals. Quartz and various amounts of calcite, fluorite, and barite always accompany these ore minerals. Dark or banded quartz are good indicators of nearby ore while white or "bull" quartz is usually found in unproductive portions of a vein or ore body. The size of the deposits can range widely, from 50,000 tons to as much as 15 million tons. Gold content can range from over one ounce per ton to a few parts per million. It is not uncommon to find ore shoots within ore bodies that are extremely rich. Silver content can range from 0.5 ounce per ton to 18 ounces; copper 0.1 to 1.0 percent; lead 0.01 to 3.0 percent; zinc 0.01 to 5.0 percent.

Alteration: During the mineral formation stage large amounts of quartz are involved which frequently results in a silicification or jasperoid zone above the ore zone. Acid-leach alteration may occur above and below the zone in the form of argillization or quartz-illite. Kaolinite, montmorillonite, alunite, and zeolites can also occur as irregular patches depending on the host rock type. The alteration may be widespread and extend for considerable distances away from the productive zone. Along vein types deposits, quartz and adularia are nearly always found, but the amount may be variable.

Ore Controls: Deposits of this type require open spaces provided by a throughgoing braided fracture system. A sudden change in attitude of a fault or an intersection with another fault will nearly always cause a change in the mineralization. In wide quartz veins, the ore may form either in the footwall or the hanging wall of the vein system. Many deposits show a gradual decrease in precious metal values downward on the vein and a general increase in base metal.

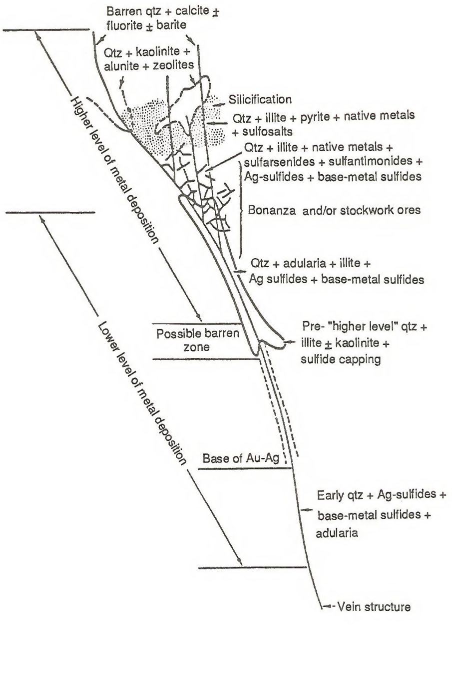
Weathering: Areas of bleached country rock may be present that may or may not be accompanied with a gossan cap. Clay material is often present in flat areas protected from erosion. Weathering of the upper part of a deposit may concentrate gold into rich residual placer deposits.

Geochemical Expression: The most useful and consistent elements accompanying this type of mineralization are arsenic, antimony, and mercury. Closer to the center of the deposit, anomalous amounts of gold and/or silver are sometimes exhibited depending on the level of erosion of the deposit. Anomalous amounts of lead and zinc can indicate that just the roots of the mineral system are all that are left in the erosion cycle.

Geophysical Expression: No distinct gravity or magnetic signature has been found associated with the ore itself, but both of these methods can be used to infer favorable associated structures.

Associated Mineralization: The erosion of high grade deposits can form rich gold placers for several miles downslope from the original deposit.

Deposit Examples:	References:
Katherine (AZ)	Lausen, 1942
Kofa (AZ)	Jones, 1916
Oatman (AZ)	Lausen, 1942
Sheep Tanks (AZ)	Wilson et al., 1967
Bodie (CA)	Silberman et al., 1972
Calistoga (CA)	Hanks and Irelan, 1887
Monitor (CA)	
Bonanza (CO)	Burbank, 1932
Creede (CO)	Stevens and Ratte, 1960(a)
Telluride (CO)	Burbank, 1941
Flathead (MT)	Ross, 1960
Aurora (NV)	Vanderberg, 1937
Bellehelen (NV)	Spur, 1903
Bovard (NV)	Ross, 1961
Bullfrog (NV)	Kral, 1951
Bruner (NV)	Kral, 1951
Como (NV)	Stoddard and Carpenter, 1950
Comstock (NV)	Becker, 1882
Cornucopia (NV)	Granger et al., 1957
Divide (NV)	Knopf, 1921
Eagle (NV)	Hill, 1916
Eastgate (NV)	Vanderburg, 1940
Fairview (NV)	Greenan, 1914
Gold Circle (NV)	Rott, 1931
Jarbidge (NV)	Schrader, 1923
National (NV)	Lindgren, 1915
Rawhide (NV)	Vanderburg, 1937
Sand Springs (NV)	Vanderburg, 1940
Searchlight (NV)	Callaghan, 1939
Seven Troughs (NV)	Vanderburg, 1936
Silver City (NV)	Stoddard and Carpenter, 1950
Tonopah (NV)	Bonham and Garside, 1979
Tuscarora (NV)	Nolan, 1936
Wonder (NV)	Vanderburg, 1940
Mogollon (NM)	Ferguson, 1927
Nogal (NM)	Lindgren et al., 1910
Steeple Rock (NM)	Lindgren et al., 1910
Blue River (OR)	Callaghan and Buddington, 1938
Gold Mountain (UT)	Callahan, 1938
Gold Spring (UT)	Butler et al., 1920
State Line (UT)	Butler et al., 1920
Republic (WA)	Lindgren and Bancroft, 1914



Idealized cross-section of an Au-Ag-base
metal deposit (from USGS Open File Report 83-423)

Deposit Type: EPITHERMAL GOLD AND SILVER

Subtype: Quartz-alunite

Synonym: Enargite gold

Description: Gold, pyrite, and enargite in vuggy veins and breccia within zones of advanced argillic alteration related to felsic volcanism

GEOLOGIC FEATURES

Regional Setting: Although these deposits are found in a variety of tectonic settings, they are most commonly found in island arcs and back-arc spreading areas.

Structural Features: A throughgoing fracture system or ring fracture zones of caldera or domal structures are commonly associated with this type of mineralization. In some deposits, graben structures and/or normal faults are the primary feature.

Stratigraphic and Lithologic Features: The deposits are found associated mainly with intermediate calc-alkalic rocks. Most common are rhyodacites, trachyandesites, or quartz latites that are nearly always porphyritic having large phenocrysts. Occasionally, sedimentary volcanic clastics are the mineral host, but intermediate intrusive and/or extrusive volcanics are nearly always found in the near vicinity.

MINERAL CHARACTERISTICS

Deposit Features: Mineralization forms in fault breccias and/or fill open-space fractures as the result of breakage of advanced argillic alteration. The ore bodies are frequently irregular, crudely pipe-like, or tabular in shape. They are also often porous and vuggy. Metal values usually range from 0.04 to 0.3 ounces/ton for gold and 0.12 to 2.1 percent for copper. High grade ore often exceeds one ounce of gold and one percent copper/ton. Most deposits range in size from 50 thousand to 5 million tons. The ore minerals are usually enargite, tetrahedrite, and in some cases silver sulfosalts. Gold is probably present in ubiquitous pyrite although occasionally native gold is found. Varying amounts of bismuthinite, tellurides, chalcopyrite, galena, and sphalerite occur in some deposits. Gangue minerals are usually quartz and varying amounts of barite, alunite, and kaolinite, illite, and montmorillonite. Most, if not all known deposits, are believed to be Cenozoic in age, but can be any age

Alteration: Pervasive argillic alteration in the mineral zone and in the surrounding host rocks is characteristic of this model type. Quartz, alunite, kaolinite, illite, and montmorillonite are common alteration assemblages that form around feeder conduits for hydrothermal solutions. Not all of these minerals may be present in an individual deposit or district. Which ones develop depend on intensity of leaching, total sulfur concentration, and amount of alkalis in the hydrothermal solution. Propylitized rocks may be found ringing the argillic zone or as patch occurrences at the outer edges. Ore bodies are always found in or adjacent to the more advanced argillic zones.

Ore Controls: Mineralization and the accompanying alteration always is found along highly permeable structured features such as faults or stratigraphic features i.e., coarse clastic or volcaniclastic beds, flow breccias, or lithologic contacts. Original rock type appears to influence alteration patterns only through permeability, not compositional control, and has no significant influence on localization of the ore. Some deposits exhibit a zoning of base metals at the outer edges of the productive areas.

Weathering: Oxidation of the ubiquitous pyrite in the argillic zone produces outcrops of gaudy yellow, brown, orange, or red limonite stains. Relict textures of the original ore minerals and host rock minerals may be preserved.

Geochemical Expression: Rock samples in the argillic alteration zone have been used successfully to detect mineralized areas. Anomalous amounts of gold, silver, arsenic, antimony, lead, bismuth, mercury and possibly tellurium, selenium, molybdenum are indicative of possible mineralization. Stream sediment and soil samples are most likely to show anomalous amounts of silver, lead, and bismuth if the area is mineralized.

Geophysical Expression: Magnetic methods may be useful in determining the extent of argillic alteration under cover and down dip. Various electrical methods might be used, but interpretation of results may be difficult because of varying amounts of disseminated pyrite and clay alteration.

Associated Mineralization: Some deposits are found above and along the periphery of porphyry copper deposits giving some credence to the supposition that enargite-gold type deposits may be a shallow-level indicator of deeper porphyry systems.

Deposit Examples:	References:
Masonic (CA)	Eakle and McLaughlin, 1919
Mohave (CA)	Troxel and Morton, 1962
Stedman (CA)	Wright et al., 1953
Red Mountain (CO)	Burbank, 1941
Summitville (CO)	Stevens and Ratte, 1960
Borealis (NV)	Mosier and Menzie, 1983
Goldfield (NV)	Ransome, 1909
Peavine-Wedekind (NV)	Overton, 1947
Pyramid (NV)	Overton, 1947

Deposit Type: HOT SPRINGS GOLD-SILVER

Description: Shallow, epithermal, disseminated and/or stockwork occurrences of hot-spring origin gold and silver found usually in felsic volcanic or volcaniclastic rocks.

GEOLOGIC FEATURES

Regional Setting: All known deposits of this type are found in regions of the Great Basin that have had significant volcanic activity resulting in felsic intrusive and extrusive rocks. Most occurrences are Tertiary and younger in age.

Structural Features: Areas of complex high-angle faulting found at caldera margins, resurgent domes, horst and grabens, or large, strike-slip faults with accompanying normal splays are the most favorable for these deposits. Hydrothermal brecciation and minor explosive volcanic activity such as breccia dikes are other features that are commonly exhibited in these deposits.

Stratigraphic and Lithologic Characteristics: The host rocks are nearly always volcaniclastics, lake beds, tuffaceous sandstones, or volcanic tuff breccias. Whatever the rock type, it must have a relatively high degree of permeability. This model type represents the surface or near-surface expression of a venting geothermal spring system.

MINERAL CHARACTERISTICS

Deposit Features: By their very nature, deposits of this kind are low grade but of large tonnage. Gold content commonly ranges from 0.05 to 0.20 ounces/ton, and silver may range upward to 1 ounce/ton. Reserves can range up to 50 million tons. The bulk of the mineralization is disseminated into a favorable rock type or zone. Veins and stringers that generally accompany these deposits are usually enriched, particularly at the surface due to weathering of the more soluble components. Pyrite is common, often imparting a gray or bluish color to the quartz. Frequently, the gold and silver mineralization is accompanied by stibnite, arsenopyrite, fluorite, and sulfur. Various types of hydrothermal quartz are always present along with adularia, sericite, kaolinite, and alunite. Besides gold and silver, there may be enough mercury and alunite present to warrant recovery.

Alteration: There is evidence of zoning at some deposits, but it is highly variable. A central area of massive silicification followed by an argillic zone and/or phyllic alteration is sometimes found. The alteration pattern seems to vary with the rock types present and the composition and intensity of the geothermal system.

Ore Controls: A high degree of permeability of the host rocks and a through-going fracture system is necessary to localize the ore solutions. Some fractures may be induced through hydrothermal brecciation and minor explosive volcanic activity.

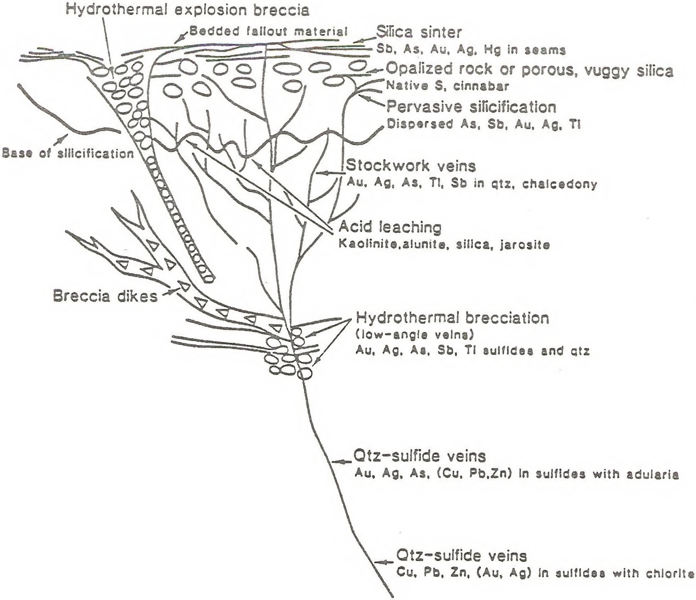
Weathering: The high pyrite content of the host rock will generally oxidize into light browns, tans, reds, and white along with general bleaching of the rocks by geothermal action. Coloring is due to mixtures of limonite, hematite, goethite, jarosite, and alunite.

Geochemical Expression: Trace elements are present in the altered zones but are highly variable. Arsenic, mercury, antimony, and thallium are commonly found in anomalous amounts especially in the upper portions of the deposit and decreasing with depth.

Geophysical Expression: Little is known of any diagnostic signature above deposits of this type. It has been suggested that enhanced infrared photography might delineate argillic areas surrounding these deposits.

Associated Mineralization: Epithermal precious metal quartz veins and base metal sulfides may lie at depth.

Deposit Examples:	References:
McLaughlin (CA)	Averitt, 1945
DeLamar (ID)	Lindgren, 1900
Hasbrouck Peak (NV)	Bonham and Garside, 1979
Round Mountain (NV)	Tingley and Berger, 1980
Sulphur (NV)	Wallace, 1980



Idealized section through a hot-springs gold-silver type deposit (from USGS Open File Report 83-423)

Deposit Type: DISSEMINATED MERCURY

Synonym: Volcanic mercury

Description: Stratabound disseminated mercury minerals in volcaniclastic and associated sedimentary rocks.

GEOLOGIC FEATURES

Regional Setting: Nearly all deposits of this type have been found within and around the borders of volcanic centers located along major deep-seated fault zones.

Structural Features: Some sort of fracture system is required to give access to the ascending mineral solutions, but most any type of fault, fracture, or jointing seems to suffice for a channel way.

Stratigraphic and Lithologic Characteristics: These deposits are typically found in andesite lava flows and tuffs, andesite dikes, and volcanic vent breccia of Tertiary age. A few are found in shale, graywacke, and calcareous graywacke. The pore space in a rock unit is usually the critical factor in localizing the mineral solutions.

MINERAL CHARACTERISTICS

Deposit Features: Size and shape of the various known deposits vary greatly. The mineralization is disseminated into favorable rock units cut by fractures and faults. Mercury content diminishes outward from the fracture feeder zones. Where permeable rock units are not available, mineralization is severely limited to small fractures and veinlets in discontinuous zones. Depth of these deposits is usually only 100 to 300 feet. Material considered "ore" varies with the current market price and the mining method employed but usually ranges from 3 to 12 pounds of mercury per ton. Cinnabar is usually the only mercury mineral present and is accompanied by abundant pyrite or marcasite and occasionally small quantities of chalcedony, quartz, and calcite.

Alteration: The conspicuous lack of alteration of wall rock to clay is one of the characteristics of this type of deposit.

Ore Controls: Localization of cinnabar is controlled mainly by steeply dipping fracture and faults (that have had only small movement) cutting permeable rock units.

Weathering: The chemical weathering of the pyrite or marcasite in the ore zone usually produces jarosite and gypsum in the outcrop area. Some clay minerals may also be present depending on the types of enclosing rocks, the degree of weathering, and the topography.

Geochemical Expression: Besides anomalous amounts of mercury in the general ore zone, arsenic and antimony are commonly found.

Geophysical Expression: Very little information is available on the geophysical signature of this type of deposit. The pyrite or marcasite in the ore should lend itself to detection by electro methods if the weathering is not too deep.

Associated Mineralization: Stibnite veins are known to occur occasionally in the general vicinity of these deposits.

Deposit Examples:	References:
A&B (NV)	Bailey and Phoenix, 1944
Berry Creek (NV)	Bailey and Phoenix, 1944
Castle Peak (NV)	Bailey and Phoenix, 1944
Castle Rock (NV)	Bailey and Phoenix, 1944
Cinnabar Hill (NV)	Bailey and Phoenix, 1944
Diamonfield (NV)	Bailey and Phoenix, 1944
Finger Rock (NV)	Bailey and Phoenix, 1944
Hillside Mercury (NV)	Bailey and Phoenix, 1944
Nevada Cinnabar (NV)	Bailey and Phoenix, 1944
Poinsetta (NV)	Bailey and Phoenix, 1944
Red Bird (NV)	Bailey and Phoenix, 1944
Red Cloud (NV)	Bailey and Phoenix, 1944
San Pedro (NV)	Bailey and Phoenix, 1944
Walker (NV)	Bailey and Phoenix, 1944
Washington (NV)	Bailey and Phoenix, 1944
Black Butte (OR)	Wells and Waters, 1934
Blue Boy (OR)	Ross, 1942
Lucky Strike (OR)	Ross, 1942
Red King (OR)	Ross, 1942
Sesena Creek (OR)	Ross, 1942

Deposit Type: SILICA-CARBONATE MERCURY

Synonym: New Almaden type

Description: Cinnabar replacement of silica-carbonate rocks resulting from hydrothermal alteration of serpentine intruded into graywackes and siltstones.

GEOLOGIC FEATURES

Regional Setting: Nearly all the deposits are believed to have occurred in accreted bodies of rock in the upper plate of thrust faults in major subduction zones. All known deposits are of Tertiary age.

Structural Features: Usually found near sills and dikes of serpentine intruded into sedimentary rocks.

Stratigraphic and Lithologic Characteristics: The most important deposits have formed in shattered zones of Franciscan graywacke, siltstone, chert, and limestone above sloping serpentine intrusives.

MINERAL CHARACTERISTICS

Deposit Features: Mineralization occurs as veins, veinlets, and impregnation in fractured rocks near and within fault zones. Minerals are cinnabar, metacinnabar, and minor amounts of pyrite, stibnite, chalcopyrite, sphalerite, galena, and bornite. Grade of ore commonly ranges from 0.20 to 0.75 percent mercury/ton. Size of the deposits can range from as low as 1400 tons to as much as 750,000 tons. Most deposits are nearer the lower range.

Alteration: These deposits have formed as the result of hydrothermal action that has commonly replaced the serpentine at the contact with quartz and dolomite to form the silica-carbonate rock that is the host rock.

Ore Controls: Especially favorable situations are where the ore solutions have permeated along a serpentine-siltstone contact. At the contact with other rock types, the serpentine may be mineralized but to a lesser degree.

Weathering: No particular diagnostic features other than the formation of the white silica-carbonate rock. This may weather faster than the surrounding rocks and be covered on undisturbed outcrops.

Geochemical Expression: Little is known about the geochemical anomalies above deposits of this type. Probably high amounts of mercury and antimony would be found and possible copper and zinc.

Geophysical Expression: No published investigations are known.

Associated Mineralization: A few deposits have small stibnite veins nearby and within the mercury mineralization. In most cases they are of minor importance.

Deposit Examples:	References:
Abbott (CA)	Becker, 1888
Aetna (CA)	Becker, 1888
Bella Oak (CA)	Ransome and Kellog, 1939
Chicago (CA)	Ransome and Kellog, 1939
Contact (CA)	Bradley, 1918
Corona (CA)	Ransome and Kellog, 1939
Culver-Bear (CA)	Ransome and Kellog, 1939
Dewey's (CA)	Bradley, 1918
Esperanza (CA)	Ransome and Kellog, 1939
Great Eastern-Mt. Jackson (CA)	Becker, 1888
Harrison (CA)	Averitt, 1945
Helen (CA)	Ransome and Kellog, 1939
Keystone (CA)	Becker, 1888
Knoxville (CA)	Averitt, 1945
La Joya (CA)	Ransome and Kellog, 1939
La Libertad (CA)	Ransome and Kellog, 1939
Lion Den (CA)	Ransome and Kellog, 1939
Manhatten (CA)	Averitt, 1945
Mirabel (CA)	Ransome and Kellog, 1939
Mt. Diablo (CA)	Becker, 1888
New Almaden (CA)	Bailey and Everhart, 1964
Patriquin (CA)	Ransome and Kellog, 1939
Polar Star (CA)	Becker, 1888
Red Elephant (CA)	Averitt, 1945
Red Rick (CA)	Bradley, 1918
Reed (CA)	Averitt, 1945
Socrates (CA)	Ransome and Kellog, 1939
Soda Springs (CA)	Averitt, 1945
Twin Peaks (CA)	Ransome and Kellog, 1939
Wall Street (CA)	Becker, 1888

Deposit Type: HOT SPRINGS MERCURY

Synonym: Sulphur Bank type

Description: Dissemination of cinnabar and pyrite in predominantly volcanic sediments, intrusives, and extrusives associated with recent or paleo hot springs system.

GEOLOGIC FEATURES

Regional Setting: Generally centered around areas of Tertiary intermediate to mafic volcanic activity accompanied by normal faulting.

Structural Features: Favorable conditions are found in areas of fossil hot springs and at the water table level that existed during hot springs activity.

Stratigraphic and Lithologic Characteristics: Host rocks are most commonly extrusive flows ranging from andesite to basalt, andesite tuffs and tuff breccias, and diabase dikes. The critical feature is that the rock types must be either permeable or brittle enough to readily develop fractures for mineral solution access.

MINERAL CHARACTERISTICS

Deposit Features: Mineralization consists principally of cinnabar, native mercury, metacinnabar, and cordierite finely disseminated in microscopic crystals and aggregates in permeable rocks. It can occupy intergranular spaces in the groundmass, coat fragments, line vugs and gas cavities, and is commonly intergrown with euhedral quartz. Size of the deposits is generally small, ranging from 250 to 490,000 tons. Grade varies over a narrow range of 0.20 to 0.60 percent/ton. Associated with the mercury mineralization is stibnite, pyrite, marcasite, dolomite, calcite, opal, cristobalite, and anatase.

Alteration: Hydrothermal alteration is pervasive with the formation of kaolinite, halloysite, sericite, jarosite, and montmorillonite. Alteration will vary with the rock types involved and the intensity of the solutions. In the upper parts of the hot springs system, native sulfur may be present.

Ore Controls: High angle faults and attending fractuces that intersect the paleo ground-water level within a hot spring system are the favorable conditions necessary for mineral deposition.

Weathering: Alteration will soften the enclosing rocks and along with weathering action will generally cause rapid erosion. Any quartz deposited in the form of quartz veinlets, sinter, and opalite as the result of the hot spring action will naturally be more resistant and may form a more or less resistant outcrop.

Geochemical Expression: Anomalous amounts of mercury, arsenic, and antimony can be expected in the nearby vicinity, also possible anomalous amounts of gold. Some studies suggest present thermal waters very high in carbon dioxide, boron, ammonia, sodium, and iodine, and low in silica and potassium may be indicative of mercury deposits of this type.

Geophysical Expression: No characteristic geophysical signature has been documented around deposits of this type.

Associated Mineralization: Although antimony and arsenic are frequently associated with the mercury mineralization, they are not usually present in recoverable amounts. It has been suggested that gold may be present at depth or nearby since the chemical and physical conditions are similar for a deposit of this type.

Deposit Examples:	References:
Sulphur Bank (CA	White and Roberson, 1962
Walibu (CA)	Averitt, 1945
Idaho Almaden (ID)	Ross, 1956
Baldwin (NV)	Bailey and Phoenix, 1944
B and B (NV)	Bailey and Phoenix, 1944
Butte (NV)	Bailey and Phoenix, 1944
Coleman (NV)	Bailey and Phoenix, 1944
Corders (NV)	Bailey and Phoenix, 1944
F and L (NV)	Bailey and Phoenix, 1944
Goldbanks (NV)	Bailey and Phoenix, 1944
Governor (NV)	Bailey and Phoenix, 1944
McDermitt (NV)	Bailey and Phoenix, 1944
Nevada Sulphur (NV)	Bailey and Phoenix, 1944
Rim Rock and Homestake (NV)	Bailey and Phoenix, 1944
Steamboat Springs (NV)	Bailey and Phoenix, 1944
Glass Butte (OR)	Ross, 1942
Opalite (OR)	Yates, 1942

Deposit Type: VOLCANOGENIC URANIUM

Description: Uranium mineralization in an epithermal assemblage of quartz, fluorite, and iron, arsenic, and molybdenum sulfides.

GEOLOGIC FEATURES

Regional Setting: Generally found in continental rift areas that have associated calderas. Age can range from Pre-Cambrian to Tertiary.

Structural Features: Usually associated with subaerial to subaqueous volcanic complexes of high silica alkali rhyolites and potash trachytes. Igneous rocks can be either shallow intrusives or vesicular flows.

Stratigraphic and Lithologic Characteristics: Peralkaline and peraluminous rhyolite are favored host rocks. Texture of the volcanics can range from porphyritic to microcrystalline.

MINERAL CHARACTERISTICS

Deposit Features: A typical deposit can have a grade of 0.02 to 0.3 percent uranium oxide and a size ranging from 20,000 tons to 6 million tons. Ore minerals are commonly coffinite, uraninite, and brannerite accompanied by pyrite, realgar and orpiment, jordisite, leucoxene, fluorite, quartz, adularia, and barite. Minor amounts of gold are found in some deposits, and it is not uncommon to find bastnaesite associated with alkaline complexes.

Alteration: Kaolinite, montmorillonite, and alunite are commonly formed in the ore zone. Also, silicification and the development of adularia are often found in the wall rock and mixed in with the ore minerals.

Ore Controls: A pervasive system of fractures and breccia along the edges and margins of intrusives direct the ore solutions. Where extrusive rocks were exposed to ore solutions, permeable units are important.

Weathering: Shallow weathering will produce a variety of uranium oxide minerals. Supergene secondary enrichment does not significantly develop.

Geochemical Expression: Anomalous amounts of arsenic, antimony, fluorine, and molybdenum are usually found in the ore zone. Rare earth elements may also be present (bastnaesite). Mercury and lithium are usually found at the edges of the mineralization and molybdenum near the bottom of deposition.

Geophysical Expression: No characteristic signature is known for deposits of this type.

Associated Mineralization: Roll-front type uranium deposits may develop in associated volcaniclastic sediments.

Deposit Examples:	References:
Anderson (AZ)	Sherborne, et al., 1979
McDermitt (NV)	Rytuba and Glauzman, 1979
Aurora (OR)	Roper and Wallace, 1981
Lakeview (OR)	Cohenour, 1960
Marysville (UT)	Kerr, et al., 1957
Spor Mountain (UT)	Lindsey, 1977
Thomas Range (UT)	Staatz and Carr, 1964

Deposit Type: SUBAERIAL VOLCANOGENIC MANGANESE

Synonym: Epithermal manganese

Description: Epithermal veins of manganese mineralization filling faults and fractures in subaerial volcanic rocks.

GEOLOGIC FEATURES

Regional Setting: All known deposits of this type are associated with Tertiary age volcanic centers.

Structural Features: Ring and radial faulting typically associated with volcanic centers are important in localizing ore solution. Also, the development of breccias along major faults are favorable loci.

Stratigraphic and Lithologic Characteristics: Most deposits occur in flows, tuffs, breccias, and agglomerates. Rock types can range in composition from rhyolites, dacites, and andesites to basalts.

MINERAL CHARACTERISTICS

Deposit Features: The ore minerals are usually psilomelane, pyrolusite, braunite, wad, manganite, and rhodochrosite. Accessory minerals are commonly various iron oxides, manganocalcite, calcite, quartz chalcedony, barite, and zeolites. These deposits are found in veins that may form into bunches and pockets or as stringers, nodular masses, or as disseminations. Individual occurrences are generally small, ranging from 2,600 to 290,000 tons. The grade usually ranges from 20 to 42 percent manganese.

Alteration: The main and most significant alteration product is kaolinite.

Ore Controls: It is important to have a throughgoing system of faults and fractures and/or brecciated volcanic rocks.

Weathering: The formation of abundant manganese and iron oxide minerals mixed in with kaolinite are the most apparent products at the surface of these deposits.

Geochemical Expression: Anomalous amounts of manganese are distributed over a wide area. Patches of anomalous amounts of lead, silver, gold, and copper may occur but not consistently at every deposit.

Geophysical Expression: No characteristic signature is known.

Associated Mineralization: Epithermal gold and silver deposits are known to occur in the general vicinity of some deposits of this type.

Deposit Examples:	References:
Armour Group (AZ)	Jones and Ransome, 1919
California Group (AZ)	Jones and Ransome, 1919
Hatton (AZ)	Farnham and Stewart, 1958
J. M. Meadows Group (AZ)	Jones and Ransome, 1919
Manganese Development (AZ)	Jones and Ransome, 1919
Thurston and Hardy (AZ)	Jones and Ransome, 1919
Topock (AZ)	Jones and Ransome, 1919
U.S. Group (AZ)	Farnham and Stewart, 1958
Black Crow-San Juan (NM)	Farnham, 1961
Cliff Roy (NM)	Farnham, 1961
Gloryana (NM)	Farnham, 1961
Griffith (NM)	Mosier, 1983a
JVB Claim (NM)	Mosier, 1983a
M and M Group (NM)	Mosier, 1983a
Manganese Chief (NM)	Farnham, 1961
Niggerhead (NM)	Farnham, 1961
Phillips Lease (NM)	Mosier, 1983a
Red Hill (NM)	Farnham, 1961

Deposit Type: CARBONATE-HOSTED MANGANESE REPLACEMENT

Description: Epigenetic veins and cavity fillings of manganese mineralization in limestone, dolomite, or marble.

GEOLOGIC FEATURES

Regional Setting: Found along continental margins that have been subjected to folding and major deformation and accompanied igneous intrusions. Although the deposits can be any age, most are Paleozoic or Mesozoic.

Structural Features: Favorable regions are miogeosyncline sequences of sediments that were later intruded by small plutons or other intrusive complexes.

Stratigraphic and Lithologic Characteristics: The predominant sedimentary rocks are the calcareous types such as limestones, dolomites, and marble. The intrusives are commonly granite and granodiorite.

MINERAL CHARACTERISTICS

Deposit Features: The most common ore minerals are psilomelane, pyrolusite, rhodochrosite, wad, manganite, and rhodonite. Accessory minerals are usually calcite, quartz, barite, fluorite, jasper, and manganocalcite. Minor amounts of sulfides, such as pyrite, chalcopyrite, galena, and sphalerite, may occur in the ore zone. This mineral assemblage is found in the form of tabular veins, irregular open space fillings, lenticular pods, chimneys, or pipes. Grade of the deposits can range from 15 to 45 percent manganese. Size can vary from 1,000 to 600,000 tons, but the average deposit is 25,000 tons or less.

Alteration: Because this type of deposit frequently develops at a lime-igneous contact, skarn mineralization is commonly found in the limy members.

Ore Controls: Open space filling in porous carbonite rocks is important in emplacement of the ore minerals. Also, the igneous intrusive contacts are generally loci of mineralization.

Weathering: Limonite and kaolinite generally develop at the outcrop along with blackening of the surrounding rocks by the relatively soluble manganese oxide minerals.

Geochemical Expression: Anomalous amounts of manganese are distributed over a wide area. High amounts of copper, lead, and zinc are also possible, but these elements are not always present in the ore.

Geophysical Expression: No documented characteristic signature is known other than that associated with igneous intrusives that may or may not be mineralized.

Associated Mineralization: Silver-bearing replacement veins are known to occur in the near vicinity of some deposits. Copper, lead, and zinc are sometimes found where skarn develops but not often in commercial amounts.

Deposit Examples:	References:
Atlas (AZ)	Jones and Ransome, 1919
Crown King (AZ)	Jones and Ransome, 1919
Danville-Hanchette (AZ)	Farnham et al., 1961
Golden Gate (AZ)	Farnham et al., 1961
Hendricks-Twilight (AZ)	Farnham et al., 1961
Mammoth (AZ)	Farnham et al., 1961
No. 4 - Summit (AZ)	Farnham et al., 1961
Oregon (AZ)	Farnham et al., 1961
Waterloo (AZ)	Farnham et al., 1961
Philipsburg (MT)	Goddard, 1940
Essex and Steptoe (NV)	Crittenden, Jr., 1964
Bear Mtn. (NM)	Farnham, 1961
Birchfield (NM)	Farnham, 1961
Chloride Flat (NM)	Farnham, 1961
Kingston (NM)	Mosier, 1983b
Lake Valley (NM)	Farnham, 1961
Lone Mtn. (NM)	Mosier, 1983b
Detroit (UT)	Mosier, 1983b

Deposit Type: RED-BED COPPER

Synonym: Copper shales; sediment-hosted copper

Description: Stratabound, disseminated copper sulfides in a sedimentary sequence that have accumulated under reducing conditions.

GEOLOGIC FEATURES

Regional Setting: Deposits are restricted to intracratonic rift basins and the shallow-marine environment that developed over the filled rifts.

Structural Features: Block faulting and gentle folds are the main tectonic features present. Some reverse faults of small magnitude are present in a few deposits.

Stratigraphic and Lithologic Characteristics: The rifts are commonly filled with thick sequences of sediments, evaporites, and sometimes hypabyssal and volcanic rocks of mostly basaltic nature. The alluvium is generally oxidized red but may be gray, green, or white in color. Beds of sandstone, conglomerate, limestone, and organic-rich shales are frequently intercalated. Evaporites, when present, commonly cap this sequence. Nearly all deposits are either late Precambrian or Permian to early Mesozoic in age.

MINERAL CHARACTERISTICS

Deposit Features: Copper mineralization in any one area is restricted to one or more sedimentary zones probably dictated on original permeability and/or porosity. Sandstones and shales are the most preferred host rocks, especially units containing abundant fossil wood, algal material, and biogenic sulfur. The usual ore minerals are chalcocite and lesser amounts chalcopyrite and bornite. Pyrite is nearly always present and some deposits exhibit small amounts of native silver. Dissemination of the minerals within the host rock is frequently zoned with centers of chalcocite and bornite, a rim of chalcopyrite, and minor amounts of galena and sphalerite in the peripheral areas. Native copper may be the primary ore mineral in some deposits rather than chalcocite. Grade of the deposits can range from 0.5 to 4.0 percent copper but most are one percent or less. Values are generally concentrated in thin layers several inches thick but may range on occasion to as much as 25 feet thick. A few deposits are as large as 1 million tons, but most are much smaller. Size of the deposits ranges widely from 1.65 million to 360 million tons.

Alteration: Varying degrees of alteration may reduce the red-beds to gray, green, or white in color. Beds subjected to regional metamorphism may be changed to purple color.

Ore Controls: An oxidation-reduction interface in a low pH environment is necessary to mobilize the copper and to allow it to be redeposited and concentrated. Pyritic sediments and carbonaceous matter apparently enhances concentration of the copper.

Weathering: The effect may vary considerably depending on the paleo-climate. Copper staining and red spots from oxidized pyrite in dark limestones and shales are the most obvious features. Outcrop may be completely leached of copper and redeposited down dip.

Geochemical Expression: Anomalous concentrations of copper, lead, zinc, vanadium, and molybdenium are the elements most likely sought as pathfinders. Anomalous amounts of silver and uranium may also be present in potential mineralized area.

Geophysical Expression: None are presently known.

Associated Mineralization: Evaporites commonly overlay the red-beds and may contain extractable amounts of halite, sylvite, and gypsum.

Deposit Examples:	References:
Milan (KS)	Waugh and Brady, 1976
Runnymede (KS)	Waugh and Brady, 1976
White Pine (MI)	Ensign et al., 1968
Eureka (NM)	LaPoint, 1976
High Rolls (NM)	LaPoint, 1976
Nacimiento (NM)	LaPoint, 1976
Pintada (NM)	LaPoint, 1976
Rayo (NM)	LaPoint, 1976
Stauber (NM)	LaPoint, 1976
Zuni (NM)	LaPoint, 1976
Byars (OK)	Stroud et al., 1970
Creta (OK)	Dingess, 1976
Magnum (OK)	Johnson, 1976
Teepee (OK)	Stroud et al., 1970
Wyoming Co. (PA)	Bulter, 1938
Buzzard Peak (TX)	Smith, 1976
Copper Breaks (TX)	Smith, 1976
Crowell (TX)	Smith, 1976
Medicine Mound (TX)	Smith, 1976
Old Glory (TX)	Smith, 1976

Deposit Type: SANDSTONE URANIUM

Synonym: Epigenetic roll-front; epigenetic carbonaceous uranium

Description: Deposits, chiefly in sandstones, of uranium oxides minerals that mainly fill the pores of the host rock and replace fossil plants but also partly replace the sand grains and the cementing minerals of that rock.

GEOLOGIC FEATURES

Regional Setting: Most deposits are restricted to stable platforms or forelands, coastal plains of the continental shelf, and intermontane basins of a mobile belt within pre-foreland areas. Geosynclinal and oceanic crustal settings are unfavorable.

Structural Features: Wide continental basins of 25 to 150 miles are most favorable for regional depositions. On a smaller scale, fluvial, lacustrine, deltaic, and strand-plain features are favored over other parts of a basin. Many deposits are localized in the mid-fan facies of alluvial fans.

Stratigraphic and Lithologic Characteristics: The most favorable host rock is a medium to coarse grained sandstone composed of devitrified volcaniclastics or feldspathic material containing intercalated carbonized plant matter and/or pyrite. When units of this type are interbedded with mudstones, a situation of permeable beds restricted by impermeable beds can cause increased concentration of uranium minerals. Age of favorable host rock may range from Silurian to Tertiary.

MINERAL CHARACTERISTICS

Deposit Features: Deposits may occur as tabular bodies that lie nearly parallel to the bedding of the host rock or as roll-front structures occupying part or all of a permeable rock unit. Ore minerals are most often carnotite, coffinite, or pitchblende but can contain varying amounts of 40 or so other uranium minerals. Pyrite is almost invariably present in and around the mineralized area. Also, small amounts of selenium, molybdenum, and vanadium are commonly present in the mineralized area. Ore bodies may range from a few hundred tons to several million tons. Overall grade of ore bodies generally averages 0.2 percent U_3O_8.

Alteration: Because of the reduction-oxidation environment caused by the pyrite and carbonized plant matter, favorable sandstones are frequently altered to light gray or white but may be shades of pink, yellow, or brown depending on minerals present. Mudstones are often altered to green or gray. In roll-front deposits, the oxidized sandstone is frequently pinkish and the reduced sandstone is gray.

Ore Controls: Permeable rock units with low dips containing carbonaceous material and a sulfur source are the primary host requirements. There must be a uranium source either from granite-core mountain range or tuffaceous formation. Leaching of these sources into the favorable host unit is required for deposition and concentration of the uranium.

Weathering: May produce colorful oxidized uranium minerals of yellow, green, mottled brown, bluish and greenish black. Sandstones may have bleached appearances. Any enclosed pyrite will be oxidized forming red to brown splotches in the sandstone.

Geochemical Expression: Anomalous amounts of selenium, molybdenum, vanadium, copper, and uranium are the usual indicator elements exhibited.

Geophysical Expression: Anomalous radioactivity of the order of 5 to 10 times background count as measured by gamma-ray spectrometers is generally considered significant. Low order seismic methods might be applicable to determine thickness of favor beds and pinchouts or to detect regional unconformities that could signal favorable depositional conditions.

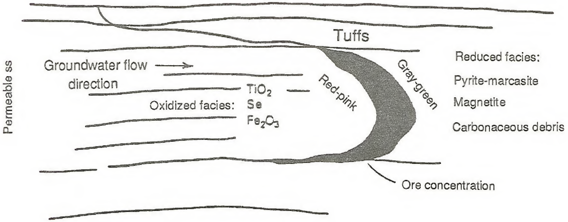
Associated Mineralization: Because of similar environment, red-bed copper deposits may occur in the same general area. Occasionally, the vanadium content of some uranium deposits is great enough to warrant recovery as a by-product.

Deposit Examples:

Nearly 4600 deposits in sandstone are known in the United States. Most of the major deposits occur within the Colorado Plateau and the intermontane basins of Wyoming.

References:

Finch, 1976
Finch, 1982
Nash et al., 1981



Idealized section across a roll-front
sandstone uranium deposit (from USGS
Open File Report 83-423)

Deposit Type: BEDDED BARITE

Synonym: Stratiform barite

Description: Fine-grained barite disseminated in stratiform bodies of layered sequences of siliceous and/or carbonate rocks.

GEOLOGIC FEATURES

Regional Setting: The rocks containing bedded barite were deposited in a wide variety of environments, but most show evidence of being deposited in eugeosynclinal areas within orogenic belts accreted to continental margins.

Structural Features: Some deposits are associated with hinge faults that are found in sedimentary basins.

Stratigraphic and Lithologic Characteristics: Almost all deposits are in well-bedded siliceous and/or limestone rocks. The deposits are frequently found intercalated with chert, shale, mudstone, argillite, and sandstone. The majority of the deposits are in Devonian rocks, but are known to occur in Cambrian, Ordovician, and lower Mississippian rocks as well.

MINERAL CHARACTERISTICS

Deposit Features: The barite may occur as very fine-grained but distinct disseminated mineral grains or as cementing material between rock grains. The overall appearance of bedded concentrations is dark gray to black layers or beds of spotty or shaley limestone. The rock frequently gives off an odor of hydrogen sulfide when freshly broken and commonly sparkles to a slight extent in sunlight. The beds are often lense-shaped or tabular and may be from a few inches to 50 feet thick. Laterally, the beds can extend over many acres but may also pinch, swell, and become discontinuous because of folding and faulting. The barite is generally found as small grains as small as 0.1 millimeter but occasionally occurs in larger masses as rosettes and nodules in the enclosing rock. Where concentrated, the beds may contain 50 to over 90 percent barite. The deposits can range from 130,000 tons to 30 million tons in size.

Alteration: Heat generated during burial or from external sources will cause originally dark colored beds to become light gray or white. This feature depends on the amount of organic carbon that is present.

Ore Controls: Depositional basins formed morphologic traps for location of barium solutions in select sedimentary units. Where barite forms a cement in sandstone and siltstone beds, it indicates migration and precipitation of barium solutions during diagenesis.

Weathering: Usually no distinct features. Generally resembles ordinary limestone or dolomite. Occasionally barite rosettes or nodules will weather out along the surface exposure.

Geochemical Expression: A high barium content in the near vicinity of a deposit along with an extremely low calcium and magnesium content is common. Associated strontium values may show as high as 7000 ppm. Where barite is found peripheral to sedimentary-hosted zinc-lead, there may be lateral zoning of copper, lead, zinc, barite, and/or regional manganese halos.

Geophysical Expression: No distinct nor diagnostic pattern is known to occur over bedded barite deposits.

Associated Mineralization: Occasionally, marine exhalant zinc-lead type deposits are found in the near vicinity but are not thought to be genetically related to the barite.

Deposit Examples:	References:
Magnet Cove (AR)	Scull, 1958
Castella (CA)	Weber and Mathews, 1967
Sun Valley (ID)	Brobst, 1958
Argenta (NV)	Ketner, 1963
Bateman Canyon (NV)	Ketner, 1963
Greystone (NV)	Ketner, 1963
Mountain Springs (NV)	Ketner, 1963
Northumberland (NV)	Shawe et al., 1969
Slaven Canyon (NV)	Ketner, 1963
Uribe (WA)	Orris, 1983

Deposit Type: PLACER GOLD

Description: Grains of elemental gold and sometimes platinum-group alloys deposited and concentrated by flowing water in gravel, sand, silt, clay, and their consolidated equivalent.

GEOLOGIC FEATURES

Regional Setting: Found in areas that were tectonically active during the Cenozoic, particularly the western coast ranges of the United States.

Structural Features: Near major fault zone areas where erosion has proceeded long enough to have repeatedly reworked the sediments.

Stratigraphic and Lithologic Characteristics: These deposits typically form where a high energy stream gradient flattens and water velocity lessens as at the inside of stream meanders, or below rapids and falls. They will also form beneath boulders, in vegetation mats, and along past strandlines lines.

MINERAL CHARACTERISTICS

Deposit Features: The gold is most often found as small flattened flaky particles that can range downward in size to fine powder. More rare are equidimensional nugget size pieces. Accessory minerals are varying amounts of magnetite, chromite, ilmenite, zircon, garnet, and rutile. None of these heavy minerals are usually present in economic quantities. Size and grade of placers vary greatly depending on the amount of original gold in the source rock, the degree of erosion to free the gold, and the amount of mechanical concentration of the freed particles.

Alteration: Not found in this type of deposit.

Ore Controls: Highly sensitive to the depositional environment. Natural impediments of water flow carrying gold particles can create traps and enhance concentration. Such features are natural riffles, transverse fractures, dikes, and joints. Particularly favorable are upturned beds of slate, schist, and phyllite that lie oblique to the stream flow.

Weathering: Because of the high specific gravity, weathering processes tend to move the gold particles through the alluvium to bedrock. Local in-place concentration may take place at the outcrop if the surface is not too steep.

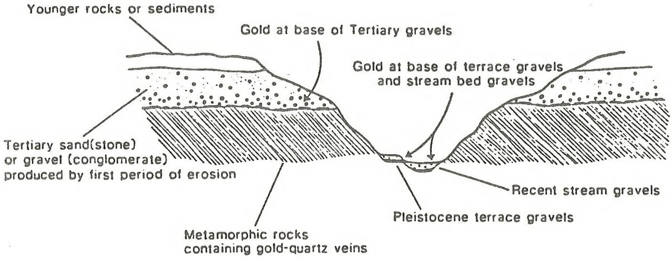
Geochemical Expression: Anomalous amounts of silver, arsenic, mercury, antimony, copper, sulfur, and iron are sometimes found with these deposits. Not all elements are always present. Also, the heavy-mineral group will be present in abnormal amounts.

Geophysical Expression: No characteristic signature other than that associated with alluvium. Placers may be cemented and give an indication of consolidated sediments.

Associated Mineralization: In areas of ultramafic complexes and serpentine, platinum group minerals may be associated with the gold in the placer deposit. Epithermal vein deposits that contributed the placer gold may be nearby.

Deposit Examples:*	References:**
AK	Brooks, 1913
CA	Lindgren, 1911
CO	Henderson, 1926
ID	Savage, 1961
MT	Koschmann and Bergendahl, 1968
OR	Brooks and Ramp, 1968

* Individual deposits are too numerous to list.
**These are general references that describe the many deposits that occur in each of the main placer-occurring states.



Idealized cross-section through a Tertiary Sierra Nevada type gold placer (from USGS Open File Report 83-901)

Deposit Type: MARINE PHOSPHATE

Subtype: Upwelling

Description: A major stratigraphic unit of phosphorite sediments within a sequence of marine beds that were formed in basins having easy access to the open sea and upwelling currents.

GEOLOGIC FEATURES

Regional Setting: Deposits are limited to former shelf and platform areas and/or areas of miogeosynclines and eugeosynclinal deformation. Age may range widely from Precambrian through Miocene.

Structural Features: Marine sedimentary basins with shoaling bottoms were the favored environment. The thickest accumulations formed in areas of geosynclinal subsidence.

Stratigraphic and Lithologic Characteristics: Where favorable marine basins have formed, a typical lateral sequence of rocks are found in a seaward direction. These consist of dark carbonaceous shale followed by phosphatic shale, phosphorite, dolomite, chert or diatomite, several facies of carbonate rock, saline beds, and red or light-colored sandstone or shale. These rocks grade laterally into each other and are also found nearly in the same order vertically or in reverse sequence.

MINERAL CHARACTERISTICS

Deposit Features: The principal primary mineral is apatite, but secondary processes include diagenetic phosphatization of calcium carbonate and interstitial precipitation, reworking by waves and currents, and weathering. More often, this changes the material into a series of undistinguishable secondary minerals and collectively called phosphorite that occurs as pellets, nodules, phosphatized shell, and bone materials. Accessory minerals are dolomite, calcite, quartz, clays, and sometimes variable amounts of iron oxide, gypsum, halite, and pyrite. Occasionally, small amounts of carnotite occur with the phosphate beds. The phosphorus zone may range up to 150 feet thick, but the mineable beds are usually only a few feet thick. Grade generally ranges from 15 to 33 percent phosphorous oxide, but the richer portions of a deposit are commonly local in extent and highly lenticular. Size of the deposits can be very large (a range from 25 million tons to as much as 3,500 million tons.

Alteration: No alteration accompanies these deposits.

Ore Controls: Stratigraphic basins or parts of basins that were favorable for the accumulation of organic-rich sediments and subsequent conditions that allowed the evolutionary processes to form phosphorites are the controlling features.

Weathering: Phosphorite breaks down easily during weathering and rarely forms natural outcrops. The presence of concealed phosphorite beds can often be detected by looking for tan to black chips of phosphorite in the soil. Highly weathered pieces have a characteristic dull-bluish-white film or bloom.

Geochemical Expression: Anomalous amounts of phosphate, nitrogen, fluorine, carbon, and uranium are usually present.

Geophysical Expression: Because nearly all marine phosphorites contain from 0.005 to 0.02 percent uranium, gamma-ray well logging can be used for identification. Under favorable circumstances, aerial gamma-ray spectrometry can be used.

Associated Mineralization: The depositional environment is conducive to possible sedimentary manganese to form in the same basins but not necessarily along with the phosphorite.

Deposit Examples:	References:
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New Cuyama (CA)	Gower and Madsen, 1964
Conda (ID)	Gulbrandsen and Krier, 1980
Henry (ID)	Gulbrandsen and Krier, 1980
Mabie Canyon (ID)	Gulbrandsen and Krier, 1980
Wooley Valley (ID)	Emigh, 1958
Warm Springs (MT)	Popoff and Service, 1965
Lee Creek (NC)	Mosier, 1983c
Uinta Mtns. (UT)	Cheney, 1957
Vernal (UT)	Cheney, 1957
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GLOSSARY OF TERMS

ANKERITIZATION. describes the introduction or replacement by ankerite. Sometimes the term ferroan dolomite is used instead.

ARGILLIC ALTERATION. the formation of new clay minerals in silicate rocks subjected to predominant acid hydrothermal solutions. The new minerals are usually kaolinite, dickite, and under some conditions pyrophyllite.

BACK-ARC BASIN. a term that describes areas lying between the active mountain building at the continental margins and the relatively stable cratonic regions in the continental interior.

CRATON. the relatively stable central portion of a continent that has been little deformed for prolonged periods.

EPIGENETIC MINERAL DEPOSIT. a deposit that has formed later than the enclosing rocks.

EUGEOSYNCLINE. the volcanic part of an orthogeosyncline located away from the craton.

GOSSAN. An iron-bearing weathered product formed by the oxidization of sulfides and overlying a sulfide deposit.

GREISEN VEINS. veins that occur in pneumatolytically altered granitic rocks and are composed mainly of quartz, muscovite or lepidolite, and topaz. Accessory minerals may include tourmaline, fluorite, rutile, cassiterite, and wolframite.

ISLAND ARC. a curved chain of islands rising from the deep-sea floor and nearer to the continents. Its curve is generally convex toward the open ocean.

INTERCRATONIC TROUGH. a graben-like structure that forms within a craton area.

LIME SILICATE ALTERATION. the replacement of carbonate sediment at an intrusive contact by lime-silicate minerals. Usually composed of various amounts of garnet, iron-rich pyroxene, epidote, wollastonite, and scapolite. The resulting rock is called skarn or tactite.

MAGMATIC CUPOLA. an upward projection of magma into the overlying rocks.

MIOGEOSYNCLINE. the nonvolcanic part of an orthogeosyncline located near the craton. Volcanism is not associated with the sediments.

OPHIOLITE. a group of mafic and ultramafic igneous rocks ranging from spilite and basalt to gabbro and peridotite, including rocks rich in serpentine, chloride, epidote, and albite derived from them by latter metamorphism, whose origin is associated with an early phase of the development of a geosyncline.

ORE DEPOSITS. A general term applied to rocks containing one or more minerals of economic value in such amounts and of such grade that they can be profitably exploited. This is different from a "mineral deposit" in that it is not yet known whether it can be profitably exploited.

ORE MINERAL. A mineral that contains a valuable or desired constituent (metallic or nonmetallic).

ORTHOGEOSYNCLINE. a regional geologic structure that contains both volcanic and nonvolcanic belts that form between continental cratons and ocean basins.

POTASSIC ALTERATION. a process that occurs as a result of greater or lesser potassium metasomatism and may be accompanied by more or less leaching of calcium and sodium in rocks containing original aluminosilicate minerals. Sometimes called K-silicate alteration.

PROPYLITIC ALTERATION. a process that is characterized chiefly by development of new calcium and magnesium minerals in igneous rocks by rearrangement of original rock-forming components by the hydrothermal process. The assemblage of minerals includes the formation of propylite, carbonates, epidate, quartz, and chlorite.

QUARTZ SERICITE ALTERATION. a process caused by the leaching of sodium, calcium, and magnesium from alumino-silicate-bearing rocks, whereas potassium may be introduced or derived from original rock-forming feldspar. Sometimes called phyllic alteration.

RESURGENT DOME. a dome that has formed by uplift following subsidence of a cauldron block.

SUPERGENE ENRICHMENT. the process where near-surface oxidation produces acidic solutions that leach metals, carry them downward, and reprecipitate them, thus enriching sulfide minerals already present.

SYNGENETIC DEPOSITS. a mineral deposit formed contemporaneously with, and by essentially the same process as, the enclosing rocks.

VOLCANICLASTIC. a clastic rock containing volcanic material in whatever proposition and without regard to its origin or environment.

The following table is a quick reference guide to assist the user in tentatively identifying mineral deposit types.

MINERAL DEPOSIT TYPES

	#2.01	#2.02A	#2.02B
Regional Setting	Continental margins having abundant igneous intrusives. Mesozoic to Tertiary in age.	Continental interior in belts of Cretaceous-Tertiary tectonic activity	Mainly on continental margins and areas of back-arc spreading
Structural Features	Most spatially or genetically related to intrusives that form stocks, plugs, sills, or dikes. Breccia and brecciation pipes common.	Commonly occur in clusters. Tend to be dome-shaped and centered on intrusive cupolas.	Generally related to the tectonic grain of Mesozoic batholiths
Stratigraphic and Lithographic Characteristics	Wide range of intrusive rocks. Most favorable are qtz. monzonite, granodiorite, and tonalite. Intruded carbonate rocks particularly favorable.	High silica, alkali-rich porphyry granites favored especially those having >250PPM Rb, >50PPM Nb, <50PPM Sr, <300PPM Ba, and enriched in fluorine.	Closely spaced qtz. veinlets in monzonites, qtz. monzonites, qtz. granodiorites, and qtz. diorites are favorable conditions.
Deposit Features	No predominant shape. Size can vary from 20 to 1100x MT. Most contain 0.6% copper. Primary minerals are pyrite, chalcopyrite, and molybdenite.	Commonly in domal, arcuate, funnel-shape, or annular bodies. Range from 50 to 900 MT. Overall grade from 0.1-0.3%; molybdenite is primary mineral.	Most are circular in size. Range in size from 15 to 700 MT. Main minerals are molybdenite and pyrite. Grade can range from 0.05 to 0.15%.
Alteration	One type always found. Five types are possible. (propylitic, argillic, potassic, quartz-sericite, and lime-silicate.	Intense in intrusive as well as in host rock. Argillic and propylitic alteration common on top and sides of deposit.	Most have potassic core followed by quartz-sericite, argillic, and propylitic alteration.
Ore Controls	Closely spaced fractures and faults as the result of folding, and doming of host rock.	Intense fracturing of intrusive and intruded rocks.	Stockwork of fractures and breccia zones within intrusive.
Weathering	Widespread iron oxide staining depending on pyrite content. Leached capping may form.	Most show iron staining but may also show black, yellow, and red variations.	Iron staining usually present but may also have yellow and green stains.
Geochemical Expression	Anomalous amounts of Cu, Mo, Au, Ag, W in central part. Pb, Zn, Au, Ag, Mo, As, Sb, Te, Mn, and Rb in peripheral areas.	Anomalous amounts of Mo, Sn, W, and Zn. Cu is abnormally low.	Many show anomalous zoning outward from Mo to Cu to Au to Ag to As.
Geophysical Expression	Some deposits situated on flanks of magnetic highs.	Possible favorable areas along margins of gravity lows.	None reported.
Associated Mineralization	Some Pb, Zn, Ag, veins found at outer fringes of system.	Sn and W may be present in enough quantities to be recovered.	Base metals in sporadic veins sometimes present in peripheral zone.

MINERAL DEPOSIT TYPES

	#2.03	#2.04	#2.05
Regional Setting	Calc-iron type related to island arcs and rifted continental margins. Mg-iron type related to continental margins.	Mostly in orogenic belts at continental margins. back-arc spreading	Mainly on continental margins,
Structural Features	Deposits form mainly at igneous-calcareous contact.	Takes on porphyry copper features in some cases. In others, no consistent recognizable features.	No particular structure. Nearby igneous - bodies probably related to zones of weakness.
Stratigraphic and Lithographic Characteristics	Associated with igneous rocks ranging from granite to gabbro. Dolomite favored over limestone. Mostly Mesozoic or younger.	Porphyry felsic stocks are favored that are Mesozoic or younger.	Wide range of calcareous sediments favorable from Paleozoic to Mesozoic. Intrusives can range from granite to syenite.
Deposit Features	Tabular to irregular along intrusive contact. Massive amounts of garnet, pyroxene, and epidote in skarn.	Irregular in size, commonly contain a mixture of chalcopyrite bornite along with pyrite, hematite, magnetite, pyrrhotite, and sphalerite.	Sphalerite and galena with small amounts of Cu, Au, and Ag. Distinctive feature is Mn minerals in skarn.
Alteration	Widespread and intense alteration of igneous rocks most often found with calc type.	Variable amounts in an interzone of potassic alteration. Hornfels and marble may form in calcareous beds.	Intense but local alteration of intrusive produces Mn accessory minerals.
Ore Controls	Fractures attending intrusive emplacement main contributor, permeability of sedimentary rocks also important.	Permeability and bedding planes of sediments important as well as intrusive induced fractures.	Skarn usually develops away from igneous contact. Lithologic contacts and faults in host rock important.
Weathering	No distinctive pattern. May show iron oxide staining and residual magnetite float.	Oxides and carbonates of copper may form and/or a gossan.	Gossan capping may form and/or iron staining.
Geochemical Expression	Anomalous amounts of Cu, Co, Au around some deposits. Calc types sometimes show Zn, Au, Ni, Mo, and Ag.	Anomalous Cu, Pb, Zn, Au, Ag, Mo, and possibly Bi.	Anomalous Ag, As, Be, Co, F, Pb, Sn, and W found in near vicinity. Zn found more distal.
Geophysical Expression	Very little known. Aeromagnetics might be used under favorable conditions.	Magnetic or electrical methods depending on mineral suite.	Little is known of any signature. Electrical or magnetic might be used under favorable conditions.
Associated Mineralization	No known associated mineralization.	Sometimes porphyry copper, zinc skarn, or Zn-Pb replacements in outer carbonate beds.	Frequently associated with copper skarns.

MINERAL DEPOSIT TYPES

	#2.06	#3.01A	#3.01B
Regional Setting	Majority of deposits related to continental areas subjected to late to post orogenic activity.	Situated along orogenic belts of continental margins.	From mainly in eugeosynclinal troughs bording volcanic domes.
Structural Features	Granitic stocks and batholiths intrudeded into calcareous sediment.	Associated with pillow lava and graben-type faulting.	Usually has graben-type faulting and display medium to high metamorphism.
Stratigraphic and Lithographic Characteristics	Argillaceous to intercalated carbonate-volcanic sequences most favorable host.	Occur mainly in lower mafic volcanics and diabase dike complexes of ophiolites that range from Precambrian to Mesozoic.	Most deposits found in volcanic sequences that grade upward from mafic to intermediate to felsic tholeiitic basalt.
Deposit Features	Forms near intrusive contact in stratiform structures and pods. Scheelite and varying amounts of Mo form ore. Skarn made up mainly of garnet and pyroxene.	Occur as tabular, lenticular, or saucer-shaped bodies in pillow lava. Consist mainly of pyrite and chalcopyrite.	Lenticular to tabular bodies of pyrite and/or pyrhotite, galena, sphalerite, and chalcopyrite.
Alteration	Nearly all alteration is in sediments where skarn forms.	Mafic rocks altered to zeolite and green-schist facies. Mn and Fe-rich cherts may be present.	Most alteration in the root zone. Chloridization and sericitization found at the sides.
Ore Controls	Dip of the host in relation to intrusive as well igneous induced fracture and faults important.	Pillow basalt structure and brecciation of mafic volcanics of prime importance. Also faults and fractures.	Zoning common with Pb at top grading downward to Zn and Cu. Large amounts of iron sulfide also commonly forms around ore body.
Weathering	Oxidation of skarn will cause iron staining.	Tan to brown gossan may form if conditions are favorable.	A lenticular gossan may form varying in color upon the minerals present.
Geochemical Expression	Above normal amounts of Wo, Cu, Mo, Bi, Be, Sn, F, and Cb usually near intrusive contact.	Anomalous amounts of Zn and Co found near center. Cu, Zn, and Co commonly found in peripheral areas.	Anomalous Pb and Au usually found in gossan. Iron sulfide halo is usually barren of Pb, Zn, Cu, Au, and Ag values.
Geophysical Expression	Magnetic and electrical methods may be useful depending on mineral suite.	Aeromatics frequently used but success depends on mineral suite.	Electromagnetics are most often used and indicated by positive anomalies.
Associated Mineralization	Occasionally Zn or Sn skarn associated with this type.	None known to occur.	Gold-quartz veins are sometimes found beneath but at considerable distance from this mineral type.

MINERAL DEPOSIT TYPES

	#3.01C	#3.02	#4.01
Regional Setting	Associated with very extensive eugeosynclinal volcanism occurring in early tectonic cycle.	Most are thought to have formed in an eugeosynclinal subduction complex that formed at the base of island arcs, oceanic ridges, and basin margins.	Spatially related to plutons.
Structural Features	No distinctive structure other than nearby high-angle faults.	Regional rocks are commonly basalt pillow lava.	Thin bedded, brittle sediments subject to fracturing and faulting from intrusive action. Favorable areas are intrusive contacts and roof pendants.
Stratigraphic and Lithographic Characteristics	Occur in thick sequences of volcanics grading upward from mafic to felsic. Most deposits are late Precambrian to Devonian.	Host is usually radiolarian chert intercalated with basalt, greenstones, tuff, and graywacke.	Intrusives are generally granodiorite or qtz. monzonite. Soluble-type sediments, such as limestones and dolomites, are usually favored.
Deposit Features	Irregular lenticular to tabular in shape. Massive pyrite and pyrrhotite with sphalerite and chalcopyrite.	Typically occurs as massive black lenses of crystalline or amorphous Mn oxide, carbonate, and manganiferous chert.	Usually irregular or podlike in shape. A wide variety of ore minerals can be present, but galena, sphalerite, and chalcopyrite are nearly always present.
Alteration	Usually found at base in the form of chloritization, sericitization, silicification, and tourmalinization.	Supergene enriched altered Mn minerals. Basalts altered to greenstones along with silicification and injection of ferriferous solutions.	Alteration limited mainly to bleaching and recrystallization of the carbonates, if present.
Ore Controls	Many located near felsic domes, calderas, and volcanic necks. Mineral zoning common with zinc at the top and increasing copper near bottom.	Faults and fractures as well as permeable beds controlled emplacement of ore.	Configuration of the intrusive and bed attitude of the host as well as joints and fractures important.
Weathering	Dark red or brown gossan found on some deposits.	Secondary Mn oxides are usually evident.	No unique weathering feature normally present. Oxidation of iron minerals may form ocher.
Geochemical Expression	Anomalous Au in gosan but no Cu or Zn except in halo area around deposit.	Anomalous amounts of Ba, Li, Rb, Zn, and Cu can be expected nearby.	Zonal arrangement of anomalous Cu at the center followed by Pb-Ag, Zn, and Mn at the outer edges.
Geophysical Expression	Electromagnetics have been used successfully. Aeromagnetics may detect sulfide bodies if enough pyrrhotite present.	None known.	Buried plutons may show as positive highs using regional aeromagnetics. Other methods not overly successful.
Associated Mineralization	Au-qtz. veins sometimes found in root zone beneath these deposits.	None definitely identified.	Some precious and base metal veins may occur in the contact zone.

MINERAL DEPOSIT TYPES

	#4.02	#4.03	#4.04A
Regional Setting	Carbonate beds deposited in an eugeosynclinal environment that later becomes tectonically active.	Found mainly along mobile belts of the continental margins, namely Central Sierra Nevada Mountains and Southeast Appalachian Mountains.	Most are located along continental margins or back-arc basins subjected to orogenic activities.
Structural Features	Moderate regional folding with many high angle faults. Dikes and plutons generally found in the near vicinity.	Orogenic folding and overthrusting causing thrust faults and secondary fractures.	Strong fracture system present such as Basin and Range faulting, caldera ring fractures, caldera-related graben structures, or complex faulting in domal areas.
Stratigraphic and Lithographic Characteristics	Carbonaceous cabonate rock are highly favored, age not critical. Associated intrusives generally range from qtz. diorite to qtz. monzonite.	Regional metamorphism has produced slates, schist, greenstones, and gneisses. Later intruded with rocks ranging from peridotites to qtz. diorite.	Brittle rocks are most favored because of the open spaces created when deformed.
Deposit Features	Micron size Au in stratiform zonal patterns encircling areas of silification. Show a spatial relation to high angle faults.	Occur as quartz veins or mineralized country rock. Au usually accompanied with pyrite, galena, sphalerite, and arsenopyrite.	Occur as veins, stockworks, and replacements in volcanic rocks and sediment hosts. Ore can be native Au-Ag, tellurides, sulfides of As, Sb, Ag, Hg, and base metals.
Alteration	Bleaching and leaching of large areas usually exhibited. Replacement of carbonates by silica and development of clays most prominent features.	Carbonization or ankeritization chief alteration feature. Wall rocks sometimes altered to sericite, pyrite, and arsenopyrite.	Silicification or jasperoid zone above ore is common. Acid leach may occur above and below the ore. Clay alteration in irregular patches.
Ore Controls	Tectonic folding of brittle host rocks creating fractures and faults.	Joints and faults in brittle host rock; slates are particularly favorable.	A throughgoing braided fracture system needed. Some may show gradual zoning from precious metals outward to base metals.
Weathering	Very little distinctive changes. Some beds may lighten in color.	Mechanical concentration can produce rich near surface and downslope placers.	Areas of bleached country rock that may have gossan cap. Clay minerals present where protected from erosion.
Geochemical Expression	Anomalous amounts of As, Sb, Hg, Tl usually found. Also higher than normal Ba, Mo, W, F frequently present.	Near mineralization, As is only mineral found in persistent amounts.	Anomalous As, Sb, Hg, Au, Ag. High amounts of Pb and Zn may indicate only roots are left.
Geophysical Expression	No distinctive pattern recognized or detectable by any present method.	No specific signature is known. Aeromagnetics have been used to map associated ultrabasic rock units.	No distinctive signature. Gravity and magnetic methods might be used to delinate favorable structure.
Associated Mineralization	Small prospects of Ag, Pb, Zn, Cu, and Hg sometimes found in near vicinity.	Some massive Cu deposits have been found in the same general region.	Erosion forms rich residual Au placers.

MINERAL DEPOSIT TYPES

	#4.04B	#4.05	#4.06
Regional Setting	Commonly found in island arcs and back-arc spreading areas.	All deposits are found in areas of the Great Basin having felsic intrusive and extrusive rocks of Tertiary Age.	Nearly all deposits found within or around the borders of volcanic centers.
Structural Features	A throughgoing fracture system or ring fracture zones associated with calderas and domal structures.	Areas of complex high-angle faulting found at caldera margins, resurgent domes, horst and and grabens, or large strike-slip faults with accompanying normal splays.	A deep seated fault zone is needed to produce a fractured system.
Stratigraphic and Lithographic Characteristics	Most deposits found associated with intermediate calc-alkalic rocks that are nearly always porphyritic.	Host rocks are usually volcaniclastics, lake beds, tuffaceous sandstones, or volcanic tuff breccias--all having high permeability.	Most are found in andesite lava flows and tuffs, andesite dikes, and volcanic vent breccia of Tertiary age.
Deposit	Forms in irregular, crude pipe-like or tabular ore bodies. Au occurs mainly within pyrite along with enargite and tetrahedrite.	Ore occurs mainly as dissemination in favorable beds or zones. Small veins and stringers may also occur and be enriched, particularly near the surface.	Size and shape of deposits vary greatly. Forms disseminations in favorable rock units. Cinnabar and pyrite always present.
Alteration	Argillic alteration in ore zone. Propylitized rocks form farther out as a ring or as patches.	A central area of silicification followed by argillic and/or phyllic alteration; but the pattern can be very irregular.	Conspicuous lack of alteration.
Ore Controls	Ore always found in the more permeable rocks, and fractured regions. Zoning may occur with base-metals at the outer fringes.	Permeability of the rocks and a well developed system of fractures are needed.	Mineralization controlled by steeply dipping fractures cutting permeable units.
Weathering	Argillic zone produces outcrops of yellow, red, orange, and brown if conditions permit.	Oxidation of the pyrite and bleaching by the alteration generally produce outcrops of tan, browns, reds, or white.	Iron staining with the possible formation of jarosite and gypsum.
Geochemical Expression	Anomalous amounts of Au, Ag, As, Sb, Pb, Bi, Hg, and possibly Te, Se, or Mo.	Anomalous amounts of As, Hg, Sb, Tl are sometimes found in the altered area, but the amount is highly variable.	Anomalous amounts of Hg, As, and Sb generally present.
Geophysical Expression	Magnetics have been used to determine extent of argillic alteration when covered. Electrical method has also been used, but results are difficult to interpret.	No particular diagnostic signature known. Infrared photos might delineate argillic areas.	Little is known of distinctive signature. Electrical methods might detect pyrite if weathering not too deep.
Associated Mineralization	Some deposits found above and along periphery of copper porphyries.	Epithermal precious metal qtz. veins and base metal sulfides may lie at depth.	Stibnite veins are known to occur occasionally in the general vicinity.

MINERAL DEPOSIT TYPES

	#4.07	#4.08	#4.09
Regional Setting	Nearly all deposits occur in accreted bodies of rock in the upper plate of thrust faults in major subduction zones.	Generally centered around areas of intermediate to mafic volcanic activity of Tertiary age.	Generally found in continental rift areas associated with calderas.
Structural Features	Usually found near sills and dikes of serpentine intruded into sediments.	Favored areas are fossil hot springs and at the fossil water table that existed then.	Usually associated with subaerial to subaqueous volcanic complexes of high silica alkali rhyolites and potash trachytes.
Stratigraphic and Lithographic Characteristics	Forms in shattered zones of graywacke, siltstone, chert, and limestone above sloping serpentine intrusives.	Host rocks are commonly extrusive flows ranging from andesite to basalt, andesite tuffs and tuff breccias, and diabase dikes.	Peralkaline and peraluminous rhyolites are favored host rocks.
Deposit	Occurs as veins, veinlets, and impregnations in fractured rocks near and within fault zones. Cinnabar and metacinnabar are major ore minerals.	Fine disseminations of mainly cinnabar and pyrite in permeable rock units.	Ore minerals are commonly coffinite, uranite, and brannerite accompanied by pyrite, quartz, fluorite, realgar and orpiment, and molybdenum sulfides.
Alteration	Hydrothermal action forms silica-carbonate rock at the contact with serpentine intrusive.	Hydrothermal alteration is pervasive with development of kaolinite, halloysite, sericite, jarosite, and montmorillonite.	Kaolinite, montmorillonite, and alunite often found in ore zone. Quartz and adularia develops in the wall rock.
Ore Controls	Especially favorable is serpentine-siltstone contact. Contacts with other rock types may be less favorable.	High angle faults and fractures intersecting paleo ground-water within a hot spring system is most favorable.	A pervasive system of fractures and breccia along the edges and margins of intrusives is needed.
Weathering	White silica-carbonate rock is about the only distinctive weathering feature.	Clay minerals will erode rapidly while any quartz sinter an opalite that formed will develop more resistant outcrops.	Shallow weathering will produce various uranium oxide minerals.
Geochemical Expression	Probably high in Hg and Sb and possibly Cu and Zn. Little is known about geochemical signature.	Anomalous amounts of Hg, As, Sb, and possibly Au can be expected in the near vicinity of mineralization.	Anomalous amounts of As, Sb, F, and Mo found in ore zone and with Hg and Li at the edges.
Geophysical Expression	None are known.	None are known.	No characteristic signature known.
Associated Mineralization	A few deposits have small stibnite vein within the mercury mineralization.	Possibly Au may be present at depth.	Roll-front type uranium may develop in associated volcaniclastic sediments.

MINERAL DEPOSIT TYPES

	#4.10	#4.11	#5.01
Regional Setting	All deposits are associated with volcanic centers of Tertiary Age.	Found along continental margins subjected to major deformation and associated igneous intrusions.	Found in intercratonic rift basins and the shallow-marine environments that developed over filled rifts.
Structural Features	Ring and radial faults and breccias developed along major faulting are important.	Miogeosyncline sequences of sediment are favorable that have later been intruded by small plutons or other intrusive complexes.	Main tectonic features are block faulting and gentle folds.
Stratigraphic and Lithographic Characteristics	Most deposits occur in flows, tuffs, breccias, and agglomerates and range from rhyolites to basalts in composition.	Calcareous sediments such as limestones, dolomites, and marble are favored. The intrusive rocks are commonly granite or granodiorite.	Thick sequence of sediments usually oxidized to red, gray, green, or white in color. May be capped with evaporites.
Deposit	Usually found in veins that may form into bunches and pockets, nodular masses, or disseminations. Psilomelane, pyrolusite, braunite, wad, and manganite are ore minerals.	Forms in tabular veins, irregular open spaces, lenticular pods, chimneys, or pipes. Ore minerals are psilomelane, pyrolusite, rhodochrosite, wad, manganite, and rhodonite.	Disseminated minerals in one or more zones of sandstone or shale, especially those containing organic material.
Alteration	Kaolinite is the most significant alteration product.	Skarn may form in the calcareous host at the igneous contact.	Varying degree of alteration and regional metamorphism may cause changes in color.
Ore Controls	A throughgoing fracture system and/or volcanic breccia are needed.	Porosity of the calcareous rocks and attitude of the igneous contact are important.	An oxidation-reduction interface and low pH needed along with carbonaceous material to enhance concentration of Cu.
Weathering	Usually a mixture of iron and manganese oxide, and kaolin forms at the surface.	Limonite and kaolinite may develop at the outcrop along with blackening of the surrounding rocks from the soluble Mn.	Copper and iron staining can occur under ideal conditions. Cu may be completely leached and deposited down dip.
Geochemical Expression	Anomalous amounts of Mn over a wide area. Anomalous patches of Pb, Ag, Au, and Cu may occasionally be present.	Anomalous amounts of Mn over a wide area and possibly high amounts of Cu, Pb, and Zn.	Anomalous amounts of Cu, Pb, Zn, V, and Mo most often found. Ag and U may also be present.
Geophysical Expression	No characteristic signature is known.	No characteristic signature known.	No signature known.
Associated Mineralization	Epithermal Au and Ag deposits are known to occur sometimes in the general vicinity.	Silver-bearing replacement veins are known to occur sometimes in the near vicinity.	Evaporites in economic quantities may overlie the red-beds.

MINERAL DEPOSIT TYPES

	#5.02	#5.03	#6.01
Regional Setting	Most deposits restricted to stable platforms or forelands, coastal plains, of the continental shelf, and intermontane basins.	Found in many environments but most are in eugeosynclinal areas within orogenic belts accreted to continental margins.	Commonly found in the western coast ranges that were tectonically active during the Cenozoic.
Structural Features	Wide continental basins having fluvial, lacustrine, deltaic, and strand-plain features are favorable.	Some are associated with hinge faults that develop in sedimentary basins.	Near major fault zones.
Stratigraphic and Lithographic Characteristics	Medium to coarse grained sandstones composed of devitrified volcaniclastics, or feldspathic material with carbonaceous material are especially favorable.	Nearly all deposits are in well-bedded siliceous and/or limestones. Many are Devonian age but may be older or younger also.	Form where high energy streams gradients flatten and water velocity lessens.
Deposit Features	Generally occur as tabular bodies or as roll-front structures occupying part or all of a permeable rock unit. Pyrite nearly always present with U minerals.	Forms in disseminations in stratiform bodies that are often lense-shaped or tabular. Barite is the ore mineral.	Gold particles usually are small flattened flaky particles ranging downward in size to powder. Accessory minerals are magnetite, chromite, garnet, and rutile.
Alteration	Sandstone altered to pale gray, brown, pink, or yellow.	Normally dark colored beds may be altered to light gray or white.	Not found.
Ore Controls	Permeability of a host rock at low dips and containing carbonaceous material is of prime importance.	Basin structure needed to trap migrating barium solutions.	Any impediment of water flow carrying gold particles can create traps and enhance concentration.
Weathering	May produce U oxides of yellow, green, brown, and black. Pyrite will produce brown patches.	No distinctive features are generally formed. Occasionally barite rosettes or nodules develop at the outcrop.	Tends to move gold particles through alluvium to bedrock.
Geochemical Expression	Anomalous amounts of Se, Mo, V, Cu, and U are indicator elements.	High Ba and Sr with very low Ca and Mg is the most common signature.	Anomalous amounts of Ag, As, Hg, Sb, Cu, S, Fe may be found but not always as a group.
Geophysical Expression	Anomalous radioactivity of 5 to 10 times background count by gamma-ray spectrometers is generally significant.	No diagnostic pattern is known.	No characteristic signature.
Associated Mineralization	Red-bed copper deposits may occur in the same general area.	Occasionally marine exhalant type Pb-Zn deposits occur in the general vicinity.	Epithermal gold veins may be nearby. In ultrabasic areas platinum may be associated with gold in placers.

MINERAL DEPOSIT TYPES

#6.02

Regional Setting	Limited to former shelf and platform areas and/or areas of miogeosynclines and eugeosynclinal deformation.
Structural Features	Favored environment is marine sedimentary basins with shoaling bottoms.
Stratigraphic and Lithographic Characteristics	Lateral sequences of carbonaceous shale, dolomite, chert or diatomite, saline beds and red or light-colored sandstone.
Deposit Features	Phosphorite occurs as pellets, nodules, shell and bone material in thick beds. May also include calcite, quartz, clays, gypsum, halite, and pyrite.
Alteration	No alteration develops in these deposits.
Ore Controls	Favorable structures are stratigraphic basins or parts of basins.
Weathering	Phosphorite weathers to a dull bluish-white film.
Geochemical Expression	Anomalous amounts of P, N, F, C, and U are usually present.
Geophysical Expression	Gamma-ray well logging can usually detect the U content. Sometimes aerial gamma-ray spectrometry has been used.
Associated Mineralization	Sedimentary Mn may be in the same general area because of similar geologic environment.

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A series of mineral models are developed to aid those involved in assessing the mineral potential of critical natural resource areas under Bureau of Land Management administration. Each model consists of a set of pertinent geologic features that are consistently associated with specific types of mineralization. The models are arranged according to five basic modes of occurrence: felsic plutonic, submarine volcanic-hosted, vein and replacement (epigenetic), sediment-hosted, and sedimentary. These represent the major mineral deposit types occurring in western United States.

17. Document Analysis a. Descriptors

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